Development of Air Quality Profile in Enclosed Car Park with Emphasis on Particulate Matter 10 µm and Carbon Dioxide

by

Ain Hidayah Binti Samadi

14435

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

SEPTEMBER 2014

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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(Dr. Nurul Izma Binti Mohammed)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specify in the references and acknowledgments, and the original work contained herein have not been undertaken or done by unspecified sources or person.

AIN HIDAYAH BINTI SAMADI

ABSTRACT

Air pollution has increased tremendously and gives the most dangerous threat compare to other pollutions because it cause the greatest adverse effects to health and loss of welfare. Statistics has shown that the increasing of pollutants available in the atmosphere is parallel to increment number of vehicles. There are few research conducted to investigate air quality inside enclosed car park. Hence, study of air pollution is significant as the first action towards improving the air quality. The aim of this study to monitor emission of particulate matter 10 µm and carbon dioxide and evaluate state of air quality inside this enclosed car park. These pollutants are analysed to determine the effect of them to human health. Enclosed car park in Kuala Lumpur has been chosen as study area. The sampling is conducted from 6th November 2014 until 17th November 2014 and data (concentration) are collected every 2 minute interval for 24 hours. The following pollutants; particulate matter 10 µm and carbon dioxide are measured by using AQM 60. This equipment is placed beside an office at this car park area. The obtained data are analysed by using time series analysis. The concentration of particulate matter 10 µm and carbon dioxide are compare with their standard guidelines which is the permissible limit to be exposed. Concentration that exceed the limit will cause health implication to visitors and employees of the car park due to long term exposure. Permissible limit for particulate matter 10 µm is 50 µg/m^3 as recommended by MAAQS for 12 month exposure and carbon dioxide is 1000 ppm recommended by U.S. EPA for continuous exposure. From the result obtained, concentration of particulate matter 10 µm exceed the allowable limit at certain hour especially at noon. It might affect the human health, especially to employees at this car park. Concentration of carbon dioxide below the limit at all time. Good maintenance is needed to maintain the concentration carbon dioxide below the limit.

ACKNOWLEDGEMENT

First and foremost, I want to express my honest gratitude to the God Almighty that with his blessing, finally completed my dissertation successfully.

High gratitude to University Technology PETRONAS (UTP) and Civil Engineering Department particularly, for acknowledging and equipping students with essential skills during the research was taking place, in series of adjunct lectures and briefing.

I would like to express the deepest appreciation to my supervisor, Dr. Nurul Izma Binti Mohammed, who has the attitude and the substance of a genius: for her continually guidance, monitoring and constant encouragement throughout the journey in completing this project.

Through every obstacles and hardship that I encounter, I would like to give my greatest appreciations to my parents, En. Samadi Bin Mat Said and Puan Zaitun Binti Abdul Jalil for always supporting me during completing this project.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The earth’s atmosphere or air is a mixture of gases. It is mainly consists of nitrogen and oxygen with 78 % and 21 %, respectively (Godish, 2004). According to Godish (2004), the remaining 1 % is encompasses of inert gases, carbon dioxide, water vapour and very small of other gases. However in the last 50 years, it is reported that the natural characteristics of atmosphere has changed which lead to air pollution to occur (Othman, 2013). Air pollution gives the most dangerous threat compare to other pollutions because it cause the greatest adverse effects to health and loss of welfare (Dominick, et al., 2012). Hence, study of air pollution is significant to overcome this pollution problem.

Pollution occurs with the presence of pollutants. Pollutants can be found in the form of particulate or gaseous phase substances, which highly in toxic or possess sufficient concentration to destruct humans, animals, vegetation or materials (Madhoun, et al., 2012). Pollutants has been categorized into two categories, which are primary pollutant and secondary pollutant. Primary pollutant is defined as pollutants that emitted directly from its source such as carbon dioxide, unburned hydrocarbon, carbon dioxide nitrogen oxides, sulphur dioxide, carbon monoxide, particulate matter and volatile organic compounds (Othman, 2013). Secondary pollutant is produced as a result of chemical reactions between two or more primary pollutants in the environment (Pundir, 2007). Ozone is an example of secondary pollutant, it produced through photochemical reaction between nitrogen oxide and unburned hydrocarbon or volatile organic compounds with presence of ultraviolet (Bhatia, 2007). Nitrogen dioxide and total suspended particulates also classified under secondary pollutant (Pundir, 2007).

The concentration of these pollutants in the air will reflect to the state of air quality on the environment (Warrington Borough Council Portal, 2012). At a certain concentration and period of exposure to pollutants will cause implication to health and other hazards (Papakonstantinou, et al., 2003), air quality standards has been introduced to express acceptable average concentration of pollutants over a period of time (Pundir, 2007). In Malaysia, it is known as Malaysian Ambient Air Quality Standards (MAAQS) as shown in Table 1.

TABLE 1: Malaysian Ambient Air Quality Guidelines
(Department of Environment Malaysia, 2014)

Pollutant	**Averaging Time**	**PPM**	**(μgm^{-3})**
Ozone	1 Hour 8 Hour	0.1 0.06	200 120
Carbon Monoxide	1 Hour 8 Hour	30.0 9.0	**35 10
Nitrogen Dioxide	1 Hour 24 Hour	0.17 0.04	320
Sulphur Dioxide	1 Hour 24 Hour	0.13 0.04	350 105
Particulate Matter (PM_{10})	24 Hour 12 Month		150 50
Total Suspended Solid (TSP)	24 Hour 12 Month		260 90
Lead	3 Month		1.5

** measured in mg/m3

According to Department of Environment Malaysia (2014), Air Pollutant Index (API) has been implemented to indicate the air quality status at any particular area. There are five major pollutants are taking into account for calculation of API, which are sulphur dioxide, nitrogen dioxide, carbon monoxide, particulate matter and ground level ozone. From the obtained range of Air Pollutant Index, the status of air pollution level to the health effect can be determined. Table 2 illustrates the range of Air Pollutant Index that applied by the Malaysian government.

TABLE 2: Air Pollutant Index (Department of Environment Malaysia, 2014)

API	Air Pollution Level
0 – 50	Good
51 – 100	Moderate
101 – 200	Unhealthy
201 – 300	Very Unhealthy
301 – 500	Hazardous
500 +	Emergency

Department of Environment (2014), reported that the main sources of primary pollutants are coming from motor vehicles, industries, development activities, electricity production and open burning. Amongst the sources, it is recognized that motor vehicles emit the highest amount of pollutants, which can cause air pollution (Dominick, et al., 2012; Fenger, 2009). Pollutants from vehicles emission caused 70 - 75 % of total air pollution while for stationary sources and open burning sources, both give 20 - 25 % and 3 - 5 % respectively (Abdullah, et al., 2012). According to Department of Statistics Malaysia (2011), for mobile source (motor vehicles), from 2008 to 2009, the emission of pollutants has grown up to 8.1 % and from 2009 to 2010, the pollutants is continuously increased about 3.8 %. The total increment recorded for mobile source from 2008 to 2010 as much as 12.2 %. Emission of pollutants by stationary source is also increasing from 2008 to 2010, however, the amount of pollutants emit by mobile source is significantly higher than stationary source for every year. The emission of pollutants by source is presented in Table 3 below.

TABLE 3: Emission of Pollutants to the Atmosphere by Source
(Department of Statistics Malaysia, 2011)

Source	Emission of Pollutants to The Atmosphere ('000 tonnes)		
	2008	*2009*	*2010*
Mobile Source	1,630.8	1,762.8	1,829.7
Stationary Source	370.1	762.2	733.1

Increment of pollutants that emit by mobile source (motor vehicles) is parallel to the growth number of vehicles registered in Malaysia (Abdullah, et al., 2012). Table 4 shows the increment of registered motorcars from year 2007 to 2012 in Malaysia and Figure 1 indicates the increment of all type vehicles.

TABLE 4: Registered Motorcars in Malaysia per Year

(Department of Road Transport Malaysia, 2014)

Year	Total
Year 2007	468512
Year 2008	537092
Year 2009	513954
Year 2010	585304
Year 2011	594610
Year 2012	628239

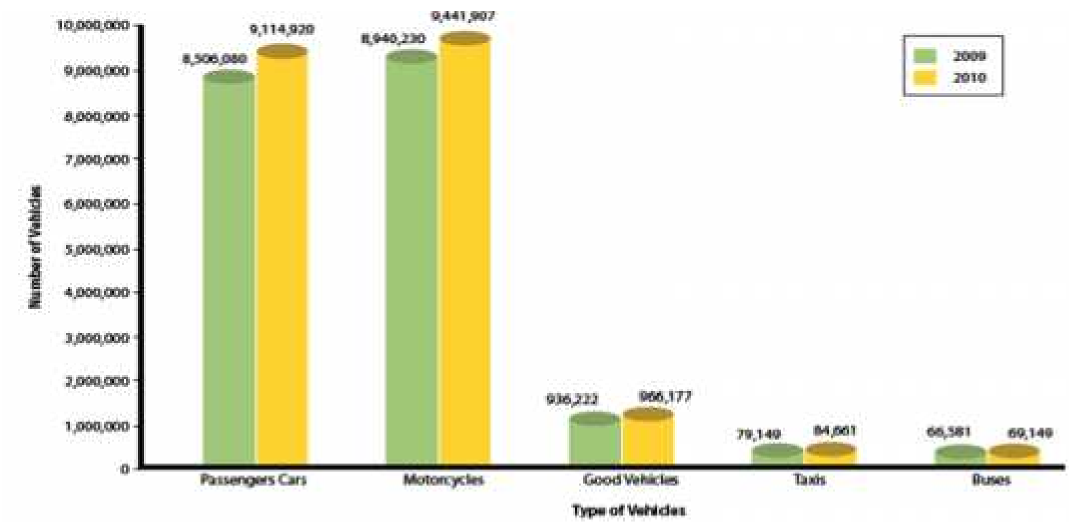

FIGURE 1: Number of Registered Vehicles in 2009 and 2010

(Department of Road Transport Malaysia, 2010)

Emission of pollutants from motor vehicles is mainly due to incomplete combustion of fuel (Wallington, et al., 2006). A state of complete combustion will occur if the engine has 100 % efficiency which provide sufficient oxygen to allow a hydrocarbon fuel source to react completely with oxygen to produce carbon dioxide and water (Beaulieu of America, 2009). However, excessive concentration of carbon dioxide also will cause hazardous effects. It is difficult to achieve 100 % of complete combustion of fuel and consequently produce pollutants such as unburned hydrocarbon, carbon monoxide, nitrogen oxides, lead, smaller proportions of suspended particulate matter, sulphur dioxide and volatile organic compounds (Schwela & Zali, 2002). Volatile organic compounds is organic compounds containing one or more carbon atoms that have high vapour pressures and therefore evaporate readily to the atmosphere. Many studies have reported that the emission of pollutants form vehicles can cause severe hazard to human health and environment (Takeshita, 2011; Middleton et. al, 2010; Petrovic & Trajkovic, 2010). The concentration of vehicle's pollutants emit depends on type of fuel used, the age and working condition of the engine, driving behaviour of the driver and quantity of fresh air supply (Chow, 1995). An issue has raise regarding air quality problem or air pollution in enclosed car park due to insufficient fresh air supply and the pollutants emit will circulate around the enclosed car park which allow the pollutants to accumulate and increase its concentrations (Sulaiman, et al., 2007; Papakonstantinou, et al., 2003).

For an enclosed car park there will be no expose to fresh air naturally but it needs to be supplied through mechanical ventilation system and it also works to remove polluted air within a rational amount of time, in order to maintain an accept able level of air quality (Viegas, 2010). Unfortunately, it is difficult to achieve the best mechanical ventilation system to perform at a particular enclosed car park (Chow & Chan, 2004). There is no specific way to know the exact concentration of pollutants will inhabited in the enclosed car park because the concentration may varies in accordance to different vehicles from time to time that using the car park. As a result, mechanical ventilation system that has been provided do not fulfil the requirements and cause air quality problem inside an enclosed car park (Sulaiman, et al., 2007; Papakonstantinou, et al., 2003). Aware with implication of air pollution in an enclosed car park especially to the health of user and car park workers has brought this study to investigate and analyse the air quality inside the enclosed car park. In this study will be focused on two pollutants that emitted by motor vehicles which are particulate matter 10 µm (PM_{10}) and carbon dioxide.

1.2 Problem Statement

Currently, number of motorcars registered in Malaysia has increased tremendously and there is a great demand for parking facilities nowadays (Li & Xiang, 2012). As a consequent, open car parks are insufficient to accommodate all the vehicles. The availability of land is limited and has become scarcer (Sulaiman, et al., 2007). Due to this reason, land is expensive and has been utilized to its fullest value (Li & Xiang, 2012) especially at urban area such as Kuala Lumpur and Selangor. To resolve this problem, multi-storey enclosed car parks have been constructed at a particular area to optimize the usage of land. Normally, lots of multi-storey enclosed car parks are found in commercial buildings, shopping mall complexes and residential buildings. The air quality inside an enclosed car park is a matter of concern.

Vehicles will emit potentially harmful substances through the combustion of fuel such as carbon dioxide, carbon monoxide, unburned hydrocarbon, nitrogen oxide, sulphur dioxide, particulate matter, and volatile organic compounds (Li & Xiang, 2012). An enclosed car park has been found associated with air quality problem due to less contact with ambient air, cause the pollutants having difficulty to diffuse and tend to accumulate (Li & Xiang, 2012). In order to maintain acceptable air quality, pollutants must be diluted and extracted completely from the enclosed car park (Lopez, et al., 2013) by practising mechanical ventilation system which, it is responsible to supply sufficient fresh air from the ambient environment (Sulaiman, et al., 2007; Papakonstantinou, et al., 2003). However, due to ineffective or malfunctioning mechanical ventilation inside to supply sufficient fresh air, allow the pollutants to accumulate inside the enclosed car park and total concentration is increased (Sulaiman, et al., 2007; Papakonstantinou, et al., 2003).

Vehicle emission contains a variety harmful substances that can give serious health implications (Takeshita, 2011; Middleton et. al, 2010; Petrovic & Trajkovic, 2010). It is very dangerous and risky for the users and workers at the enclosed car park. For the employees at the car park, they will have more potential negative effects to their health due to duration of exposure to the pollutants for a longer period of time (Papakonstantinou, et al., 2003). The car park employees may spend more than 8 hours for every day at the particular enclosed car park and constantly expose to hazardous pollutants.

In Malaysia there are few researches are carry out to study the air pollution in the enclosed car park. It is crucial to investigate and evaluate the level of air quality inside the enclosed car park with emphasis on particulate matter 10 µm (PM_{10}) and carbon dioxide. These pollutants are identified as among the contributors to poor air quality. Without any action, the air pollution in enclosed car park will become worse due to no mitigation measures taken and augmented cumulative effects to the users and car park employees.

1.3 Objective

This study has set up two objectives to be achieved. There are as follows:

1. To monitor emissions of pollutants which are particulate matter 10 µm (PM_{10}) and carbon dioxide (CO_2) from vehicles in enclosed car park of the study area.
2. To analyse concentrations level of each pollutants which are particulate matter 10 µm (PM_{10}) and carbon dioxide with temperature by using time series analysis.
3. To evaluate state of air quality by comparing concentration of are particulate matter 10 µm (PM_{10}) and carbon dioxide with standard guidelines and the impacts to human’s health.

1.4 Scope of Study

This study will be conducted at one of high prestige enclosed car park of multipurpose development area located at Kuala Lumpur City. This multipurpose building consists of shopping mall and office buildings. This place has become centre of attraction for many visitors and employees who came here with different purposes. In order to fulfil the employees and visitors demand for car park, this building has built up with five-storey enclosed car park with 5400 parking bays at the basement.

There are two sample of pollutants which are particulate matter 10 µm (PM_{10}) and carbon dioxide will be collected at this study area by using AQM 60. This equipment is placed beside an office at the car park. The temperature at this study area is recorded. For this study, a period of 10 days is allocated for the sampling (6th November 2014 – 17th November 2014). Trend of vehicles entering and leaving the enclosed car park is also observed. Result of the samples will be analysed by using time series model.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In several urban areas, the amount of air pollutants has increased with time and exceeds the levels prescribed by national ambient air-quality guidelines (Madhoun, et al., 2012). Major sources of air pollution in the Malaysia environment are coming from motor vehicles, stationary source and open burning, which, it has recorded that motor vehicles emit the highest amount of pollutants, which cause air pollution (Dominick, et al., 2012; Fenger, 2009). Motor vehicles emit highly toxic pollutants such as carbon dioxide, carbon monoxide, unburned hydrocarbon, nitrogen oxide, sulphur dioxide, particulate matter 10 μm (PM_{10}), and volatile organic compounds (Li & Xiang, 2012). In this literature, will emphasis on several pollutants from vehicle emission.

Malaysia has a stable economy which, stimulate the growth of vehicles population (Sulaiman, et al., 2007). Rapid increment of vehicles will cause severe environmental problems associated with air-quality degradation (Madhoun, et al., 2012). It also creates a great demand of parking facilities (Li & Xiang, 2012). Due to shortage of land and expensive price, many enclosed car parks are built to accommodate the vehicles. Awareness to the poor air quality at an enclosed car park has bring community to complaint because it will give health implications to the users and workers at the area as well (Chan & Chow, 2003).

Enclosed car parks are frequently construct at underground or basement of building (Sulaiman, et al., 2007). It is requires mechanical ventilation system, since air from natural ventilation is insufficient to dilute and remove all the pollutants emit by vehicles (Krarti & Ayari, 2001). Poor air quality inside enclosed car park is a result of low performance of mechanical ventilation system as the hazardous pollutants keep entrapping and accumulating (Sulaiman, et al., 2007). Mechanical ventilation system should be designed meets with the car park's requirement to remove pollutants to overcome the air quality problem. American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) has a guideline in designing mechanical ventilation system in order to achieve good air quality at an enclosed car park (Ho, et al., 2004). Unfortunately, it is difficult to estimate accurately the concentrations of pollutants from moving vehicles and different vehicles from time to time. Due to this reason, mechanical ventilation system always fail to perform at best.

2.1 Carbon Dioxide (CO_2)

The cycle of life in this world needs carbon dioxide as an important element. Carbon dioxide is required by plants to ensure the photosynthesis process occur. Carbon dioxide react with water to produce sugars and oxygen. Plant make their own food from photosynthesis process. Human and animals take up oxygen that produce by plant to sustain a life. Carbon dioxide release by human and animals will be used by plant to undergo photosynthesis process. Carbon dioxide will only become a problem to this world especially human when the concentration of carbon dioxide excessively in the atmosphere (Ndoke, 2006).

2.1.1 Source of Carbon Dioxide (CO_2)

One of the contributor for excessive carbon dioxide in this earth is vehicles. Carbon dioxide is produced by vehicle after undergo complete combustion of fuel which normally contain paraffin and aromatic hydrocarbon. The product of this combustion is carbon dioxide, water and heat. (Baldauf et al., 2004; Elsom & Longhurst, 2004). When concentration of carbon dioxide increase, temperature will increase as well (Jeremy et al., 2012). This is due to heat that also produced through this reaction. Equation 1 shows the equation for carbon dioxide production by fuel from vehicle.

$$\text{Hydrocarbon in gasoline} + O_2 \longrightarrow CO_2 + H_2O + \text{Heat} \qquad \text{(Eq. 1)}$$

2.1.2 Characteristics of Carbon Dioxide (CO_2)

Carbon dioxide is colourless, odourless and non-flammable gases. Physical properties and chemical properties of carbon dioxide are summarized in Table 5.

TABLE 5: Physical and Chemical Properties of Carbon Dioxide

Properties	Value
Molecular Weight	44.01
Specific Gravity	1.53 at 21 ^{o}C
Critical Density	468 kg/m^3
Stability	High
Water Solubility	0.9 vol/vol at 20 ^{o}C
Melting Point	-55.6 ^{o}C
Boiling Point	-78.5 ^{o}C

2.1.3 Effects of Carbon Dioxide (CO_2)

Exposure to high concentration of carbon dioxide might cause cardiopulmonary effect to human body (Harpen et al., 2004). In addition, inhaling carbon dioxide will give shortness of breath, rapid beating of the heart, sweating, headache, shaking, visual disturbance, unconsciousness and death (Centers of Disease Control and Prevention, 2012).

Nowadays, the presence of excessive carbon dioxide induce worldwide problems which is global warming (Nitrit et al., 2013). Greenhouse gases (carbon dioxide, methane, nitrous oxide and ozone) give significant effect to the rise of temperature. Greenhouse gases allow the sunlight penetrate into the earth and after some time, heat-balancing infrared rays will be emitted by the earth surface. Greenhouse gases absorb infrared radiation and re-emitted to all direction and cause the earth's surface and lower atmosphere warmer (Kakouei et al., 2012).

OSHA has set up the standard limit for carbon dioxide is 5000 ppm for 8 hours work shift. NIOSH recommended to change the permissible exposure limit to 10000 ppm per day. While, U.S. EPA stated that for continuous exposure the permissible limit is 1000 ppm.

2.2 Sulphur Dioxide (SO_2)

Sulphur dioxide is a colourless gas, non-flammable, non-explosive and relatively stable with pungent and strong odour that can easily detect at level 3 – 5 ppm (Hasernberg & Bender, 2014). Sulphur dioxide also highly soluble in water with a solubility of 85 g L-1 at 25 °C, 2.5 times as dense as ambient air, having high critical temperature (The International Volcanic Health Hazard Network, 2014). Physical properties of sulphur dioxide are summarized in Table 6.

TABLE 6: Physical Properties of Sulphur Dioxide
(Hasernberg & Bender, 2014)

Properties	Value
Molecular Weight	64.065
Molar volume at (273 K (0 °C)), (101.3 kPa)	21.9 l/mol
Melting point at (101.3 kPa)	197.5 K (–75.65 °C)
Heat of fusion (melting point)	115.6 J/g
Boiling point under 101.3 kPa	263 K (–10 °C)
Heat of vaporization (boiling point)	402 J/g
Normal density at (273 K (0 °C)), (101.3 kPa)	2.93 kg/m^3
Density at 263 K (–10 °C)	1.46 g/cm^3
Critical density	0.525 g/cm^3
Critical pressure	7.88 MPa
Critical temperature	430.5 K (157.35 °C)
Specific heat$_{cp}$ at (273 K (0 °C)), (101.3	586 J/(kg K)

kPa)	
Specific heat$_{cp}$ at (373 K (100 °C)), (101.3 kPa)	662 J/(kg K)
Specific heat$_{cp}$ at (573 K (300 °C)), (101.3 kPa)	754 J/(kg K)
Standard enthalpy of formation	–297.2 kJ/mol –4,636 J/g

2.3.1 Source of Sulphur Dioxide (SO2)

Sulphur dioxide is a dangerous pollutant, which it is produced naturally through volcanic eruptions (Foxall, 2010). Another natural source of sulphur dioxide are from decaying organic matter, solar action on seawater and oxidation of dimethyl emitted from the ocean. Nowadays, the emission of sulphur dioxide from anthropogenic sources has become substantially greater than natural sources due to the widespread combustion of sulphur-containing fossil fuel (Smith, et al., 2001), which it has contributed about 75 to 85 % out of total emission (Foxall, 2010). Mineral ore processing, petroleum refining and chemical manufacturing are classified into anthropogenic sources of sulphur dioxide emission but the emission from those sources are still lower than combustion of fossil fuel (Jacobson, 2002).

Since Malaysia does not experience any volcanic activities, emission of sulphur dioxide mainly generated by combustion of sulphur-containing fossil fuel, particularly coal and oil (Salahudin, et al., 2013). The combustion of sulphur present in fossil fuel to produce sulphur dioxide can be expressed through equation 2:

$$S + O_{2(g)} \rightarrow SO_{2(g)} \qquad \text{(Eq. 2)}$$

The composition of sulphur in coal, ranges from 0.5 % to more than 5 %, whereby, it is in both organic and inorganic forms. For oil, the sulphur content ranges from 0.001 % to more than 5 % and its sulphur is in organic form (Expert Group on Techno Economic Issues, 2012). Burning of fossil fuel at power station has become the largest sources of sulphur dioxide and it is also produce through fuel combustion of the vehicle engine (Salahudin, et al., 2013; Department of Environment Malaysia, 2010). In Malaysia, another contributor to the sulphur dioxide emission is coming from industrial sector activities (Salahudin, et al., 2013; Department of Environment Malaysia, 2010). According to Department of Environment Malaysia (2010), combustion of fossil fuel from 41 power stations around Malaysia produce 48 % out of total sulphur dioxide with amount 78,416 metric tonnes, industrial activities such as manufacturing and metal processing contributed 23% or 36,938 metric tonnes of sulphur dioxide released, combustion from motor vehicles give out 8% or 12,865 metric tonnes of sulphur dioxide and the remaining 21 % with 33694 metric tonnes contribute from others as stated in Figure 2.

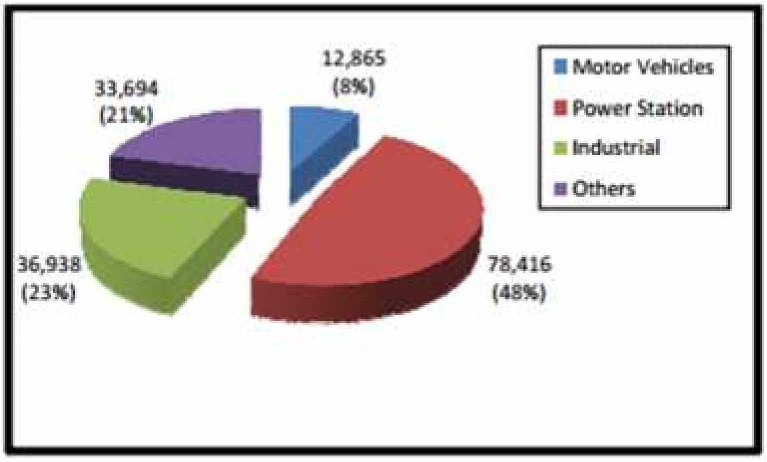

FIGURE 2: Emission of Sulphur Dioxide by Sources in Malaysia (Metric Tonnes) (Department of Environment Malaysia, 2010)

Figure 2 shows the amount of sulphur dioxide has been released to the ambient environment together with its percentage. Motor vehicles contribute the lowest emission of sulphur dioxide. However, for an enclosed car park, motor vehicle might be the main contributor to the emission of sulphur dioxide. For motor vehicles, the amount of emission is depends on type of fuel used because different fuel will give varies range of sulphur content (Colls, 2002).

The sulphur content in gasoline is very low which is less than 0.1 %, and in diesel fuel it can be up to 0.5 % of sulphur content (Hasernberg & Bender, 2014). The higher sulphur content will produce greater amount of sulphur dioxide. Table 7 summarizes the average amount of sulphur dioxide emit based on the type of fuel consumption.

TABLE 7: Average Emission of Sulphur Dioxide by Vehicle

Hasernberg & Bender, 2014)

Type of Fuel	Emission of Sulphur
Gasoline	0.37 g/l
Diesel	4.15 g/l

2.2.1 Formation of Sulphuric Acid (H_2SO_4) from Sulphur Dioxide (SO_2)

Sulphur dioxide is a precursor to formation of sulphuric acid aerosol by undergo oxidation in the gaseous phase at the atmosphere (dry reaction) or may become dissolved in water droplets and, following oxidation to form sulphuric acid aerosol droplets (wet reaction) (Jacobson 2002; Landis & Yu, 1995). This process will occur, once sulphur dioxide emitted into the atmosphere because sulphur dioxide is highly soluble in water.

Sulphuric acid is highly corrosive which is not good to the human and environment (Pritchard, 2007). The rates of sulphur dioxide oxidation processes are influenced by photochemistry and temperature and rates of oxidation of sulphur dioxide are higher in the summer than in the winter and higher in midday that at night (Laura, 2003).

Dry reaction: $$SO_{2(g)} \xrightarrow{OH+H_2O} H_2SO_4(aerosol) \quad (2)$$

Wet reaction: $$SO_{2(aq)} \xrightarrow{H_2O_2} H_2SO_4(droplet) \quad (3)$$

Figure 3 illustrates the process of formation sulphuric acid from sulphur dioxide by dry and wet reaction and both remove to the earth surface via dry and wet deposition.

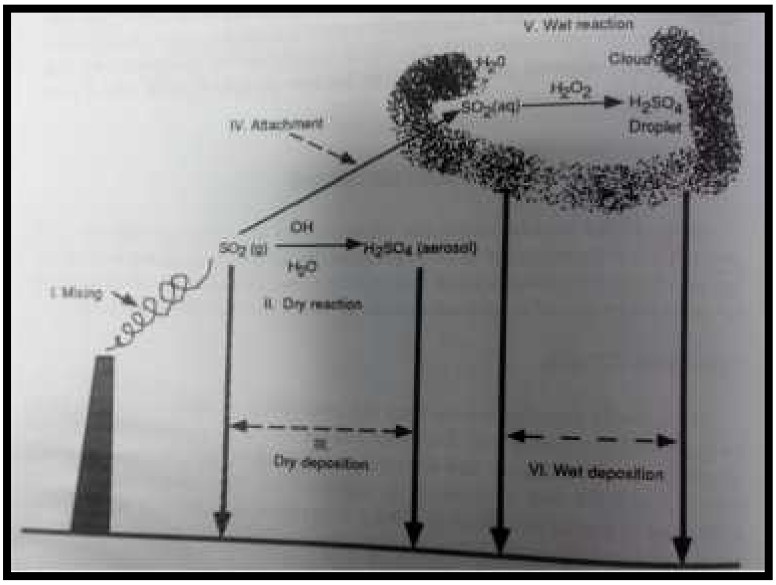

FIGURE 3: Formation of Sulphuric Acid and Removal to Earth Surface

2.2.2 Residence Time of Sulphur Dioxide in the Atmosphere

Residence time is defined as the rate of Sulphur dioxide emissions combined with the rate of removal process (deposition) (Laura, B., 2003). Residence times ranging from 1 to 5 days (Hazardous Substances Data Bank, 2002)

2.2.3 Effects of Sulphur Dioxide (SO_2)

Sulphur dioxide is an acidic gas and rapidly absorbed in the nasopharynx of human which high in concentrations will give numerous negative effects to human health (The International Volcanic Health Hazard Network, 2014). Exposure to sulphur dioxide can occur through breathing in air that contains sulphur dioxide which can cause irritation of nose, throat, wheezing, shortness of breath and tight feeling around the chest (Othman, 2013; Foxall, 2010). Nausea, vomiting, stomach pain and corrosive damage to airways and lungs are due higher exposure to sulphur dioxide (Foxall, 2010; Godish, 2004). People with asthma will be more sensitive to the effect of sulphur dioxide with concentrations as low as 0.2 – 0.5 ppm. Long term or repeated exposure will affect lung function and worsen existing heart disease

(Department of Health and Services Wisconsin, 2013). Table 8 below shows the health effects corresponds to the exposure limits.

TABLE 8: Health Effects of Respiratory Exposure to Sulphur Dioxide (The International Volcanic Health Hazard Network, 2014)

Exposure Limits (ppm)	**Health Effects**
1 - 5	Threshold for respiratory response in healthy individuals upon exercise or deep breathing
3 - 5	Gas is easily noticeable. Fall in lung function at rest and increased airway resistance
5	Increased airway resistance in healthy individuals
6	Immediate irritation of eyes, nose and throat
10	Worsening irritation of eyes, nose and throat
10 - 15	Threshold of toxicity for prolonged exposure
20+	Paralysis or death occurs after extended exposure

Sulphur dioxide can cause significant harm to the health of human, to cater this problem, Malaysia has implemented Malaysian Ambient Air Quality Guidelines for sulphur dioxide with permissible for 1-hour is 0.13 ppm (350 $\mu g/m^3$) and for 24-hour with value 0.04 ppm (105 $\mu g/m^3$). World Health Organization (2005), has come out with sulphur dioxide guideline range from 10 minutes to annual to set up an acceptable value of exposure as presented in Table 9.

TABLE 9: Ranges of Ambient Sulphur Dioxide Guideline Levels (World Health Organization, 2005)

Averaging Period	**Max (ppm)**
10 – 15 Min	0.175
1 Hour	1
24 Hour	0.153
Annual	0.038

An enclosed car park will have a tendency to possess significant level of sulphur dioxide due to fuel combustion from numerous vehicles engine. The presence of the sulphur dioxide beyond the allowable concentration will lead to poor air quality inside the enclosed car park. Concentrations of sulphur dioxide inside enclosed car park might be higher because inefficient mechanical ventilation system will permit sulphur dioxide to accumulate. Exposure to the sulphur dioxide is very hazardous to the users and workers of the particular car park. There is an issue has been raised up regarding the health effects for the workers at the car park which, expose to the sulphur dioxide environment for an extensive period of time and repeatedly. It is necessary to investigate the level of sulphur dioxide at an enclosed car park as a concern to the health effects of car park workers. According to Who Health Organization (2005), exposure as short as 10 minutes to sulphur dioxide will experience changes in pulmonary function and respiratory symptom. For this reason, no exception for users of enclosed car park not to be affected by the emission sulphur dioxide especially for children.

2.3 Volatile Organic Compounds (VOCs)

Volatile organic compounds are organic chemicals that easily evaporated at normal temperature and pressure (Tomasevic, et al., 2013). It has high vapour pressure and heavier than air. Jonathan & Ralf (2007) has defined volatile organic compounds as any carbon compounds that participate in atmospheric photochemical. The residence time of volatile organic compounds in the atmosphere is short, it just from few hours to months (Tomasevic, et al., 2013). As a result, their direct impact on radiative forcing relatively small, but their direct impact due to involvement in atmospheric photochemistry such as production of ozone in presence NOx and ultraviolet, impact on OH radical concentrations, and the production of photochemical oxidants as well as production of secondary aerosols is quite significant (Tomasevic, et al., 2013). Volatile organic compounds acts as precursors to ozone when it react with nitrogen oxide and precursors to particulate matter (Ho, et al,. 2009). Volatile organic compounds having a vapour pressure greater than 10 Pa at 25 °C and relatively low boiling point at atmospheric pressure from 50 °C up to 260 °C (Jonathan & Ralf, 2007). Due to low boiling points, volatile organic compounds often evaporate from materials containing them (Jacobson, 2002)

The major classes of volatile organic compounds emission are aromatic, alkenes, oxygenated volatile organic compounds and alkanes (Madhoun, et al., 2012). Benzene, toluene, ethylbenzene, xylenes, (BTEX) are classified under aromatic volatile organic compounds group (Madhoun, et al., 2012) whilst isoprene, monoterpenes, and sesquiterpenes, ethane, propene and 1-butene are grouped into alkenes (Roger & Janet, 2003). Oxygenated volatile organic compounds comprise of 2-methyl-3-buten-2-ol, acetone, methanol, cis-3-hexen-1-ol, cis-3-hexenyl acetate, and camphor (Roger & Janet, 2003). Ethane, propane and n-pentene are members of alkanes group (Jonathan & Ralf, 2007). Volatile organic compounds is needed in production of household cleaning products, paints, printing inks and personal care products (Conference Board of Canada, 2014).

The concentrations of volatile organic compounds are not simply increase with time at the atmosphere due to removal processes take place (sinks). An important process of volatile organic compounds removal is known as chemical oxidation in the gas phase and certain gas phase can photolyse to smaller fragments by absorbing sunlight (Jonathan & Ralf, 2007). Volatile organic compounds can be removed physically by dry deposition to surfaces and wet deposition in rain (Jonathan & Ralf, 2007). Table 10 shows the average tropospheric lifetimes of volatile organic compounds group and some selected volatile organic compounds.

TABLE 10: Average Tropospheric Lifetimes of Volatile Organic Compounds (Jonathan & Ralf, 2007)

Compound	**Average Lifetime**
Alkanes	Months - Days
Ethane	2.5 Months
Propane	2.5 Weeks
n-Pentene	4 Days
Alkenes	Days - Hours
Ethene	1.5 Days
Propene	11 Hours

1-Butene	10 Hours
Aromatic	Weeks - Hours
Benzene	2 Weeks
Toluene	2 Days
1,3,5-Trimethylbenzene	7.5 Hours

2.3.1 Sources of Volatile Organic Compounds (VOCs)

There are two sources of volatile organic compounds which are anthropogenic and biogenic (Jonathan & Ralf, 2007). Major anthropogenic sources include incomplete combustion of organic substances (fossil fuel), exhaust emission, evaporation of petroleum products such as fuel, the use of petrochemical solvent and chemical manufacturing (Olumayede & Okuo, 2011). Biogenic source of volatile organic compounds is mainly released by terrestrial plants or vegetation (Tomasevic, et al., 2013). It has been estimated that emission of volatile organic compounds from biogenic source is 1347 million tons per year (Mt/year) and 462 million tons per year (Mt/year) from anthropogenic sources (Madhoun, et al., 2012). Emission of volatile organic compounds from biogenic source are always greater than the sum of anthropogenic source based on a worldwide basis (Jonathan & Ralf, 2007). However, for an urban area emission of volatile organic compounds from anthropogenic sources has dominated due to development of industrial activities and growth of vehicles (Roger & Janet, 2003).

Figure 4 represented national volatile organic compounds emission (anthropogenic) which, it has recorded upstream oil and gas as the largest contributor to volatile organic compounds emission and following by transportation (vehicles). Vehicles release volatile organic compounds to the environment in a various ways.

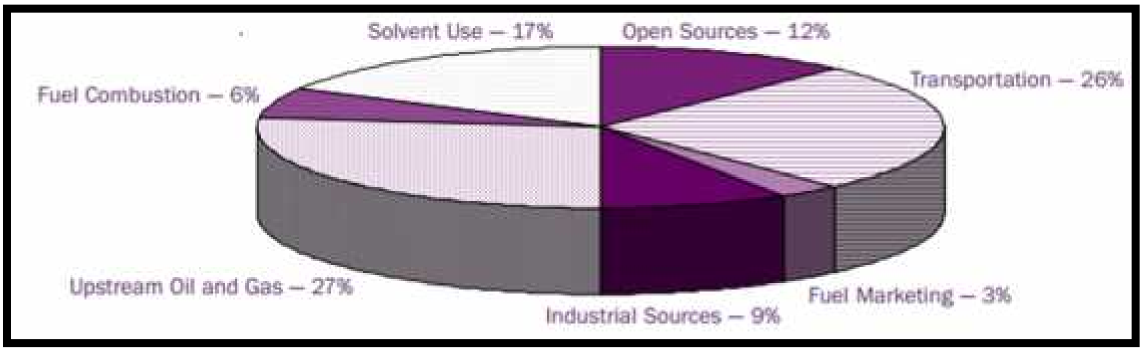

FIGURE 4: National Volatile Organic Compounds Emission (Ogilvie, 2005)

According to United State Environmental Protection Agency, for vehicle, emission of volatile organic compounds occur in two approaches which are exhaust emission and evaporative emission:

Exhaust emission is volatile organic compounds are emitted through the exhaust due to incomplete combustion of fuel in the engine while a vehicle is operating. It occurs during these two modes:

I. Cold Start - First few minutes of starting and driving vehicle could be result in higher emission of volatile organic compounds because the emissions control equipment has not yet reached its optimal operating temperature.

II. Running Exhaust Emission – Emission of volatile organic compounds during driving and idling after the vehicle warm up.

FIGURE 5: Emission of Volatile Organic Compounds via Exhaust

Evaporative emission is fuel evaporation that more encouraging to occur during hot day will escape volatile organic compounds into the air in several way:

I. Running Losses – Fuel can be vaporized through hot engine and exhaust system while running and release volatile organic compounds.

II. Hot Soak (Cooling Down) - After the vehicle is turned off, the engine will remains hot for a period of time, and fuel evaporation continues when the car is parked while cooling down.

III. Diurnal Emissions (Emission while Parked and Engine is Cool) – Fuel evaporation is still occurs when the vehicle is parked for a long period of time as the temperature rises during the day.

IV. Refueling – When the vehicle's fuel tank is being filled, fuel vapours will escape from the tank.

FIGURE 6: Emission of Volatile Organic Compounds via Evaporation

The speciation of VOC emitted from motor vehicles reflects the chemical composition of the fuel consumed, with additional species formed and emitted as products of incomplete combustion.

At enclosed car park, the major contributor to the emission of volatile organic compounds are trigger by numerous vehicles occupied the car park. It is released to the car park environment by both approaches, which are exhaust emission and evaporative emission. Poor mechanical ventilation system, will give high concentrations of volatile organic compounds.

2.3.2 Effects of Volatile Organic Compounds (VOCs)

The effects of exposing to volatile organic compounds may be vary according to the compound itself. The effects are depends on nature of the volatile organic compound, the concentrations of volatile organic compounds, and the period of exposure. Some volatile organic compounds are highly toxic and having deleterious health effects to human even at very low concentrations (Olumayede & Okuo, 2011). Certain volatile organic compounds can harm human health through inhalation, ingestion or absorption to the skin. Common short-term health effects of volatile organic compounds exposure include eye and lung irritation, effects of volatile organic compounds exposure include eye and lung irritation, long-term effects, such as damage to the liver, kidneys and nervous system (Ogilvie, 2005).

Benzene, toluene, ethylbenzene, xylenes, (BTEX) are group of dangerous volatile organic compounds and can pose jeopardies to the health (Madhoun, et al., 2012). The emission of benzene, toluene, ethylbenzene, xylenes, (BTEX) are come from various sources and mainly emitted by vehicles through combustion of gasoline and evaporative emission (normally contains benzene) (Ogilvie, 2005)

Toluene can give effects such as light-headiness, dizziness, sleepiness, unconsciousness and death by breathing high level of it in a short time. High level of toluene also will harm to the kidney. For a long term exposure, it tends to cause problems with the central nervous system and may trigger depression, difficulty concentrating, muscle weakness, memory loss, and personality changes. Unlike benzene, there is no study shown that toluene exposure can cause cancer (Glossary of Volatile Organic Compounds, 2014).

Ethylbenzene with high level exposure will give effects such as dizziness, throat and eye irritation, tightening of the chest, and burning feeling in the eyes. It also cause the central nervous system to be depress. Exposure to xylene will affect the brain. High level exposure either long or short term will result in headaches, lack of muscle coordination, dizziness, confusion, and changes in balance. Some other effects of xylene are irritate the skin, eyes, nose, and throat, and cause difficulty breathing, problems with the lungs, slow reaction time, memory difficulties, stomach discomfort, and changes in the liver and kidneys (Glossary of Volatile Organic Compounds, 2014).

Benzene is emitted from vehicles, which mostly using fuel containing benzene. Currently, composition of lead in fuel has been reduced from its initial content 0.84 grams/litre to 0.15 grams/litre and benzene is introduce to replace lead which acts as anti-knocking agent. In 2009, benzene level supposedly to be reduced from 5 % (Euro 2) volume to 1 % (Euro 4) volume (Madhoun, et al., 2012). However, Malaysia still adopted Euro 2 specifications as a consequent of unexpected economic factors. Benzene is carcinogenic which, it can cause cancer at a certain concentrations level and length of exposure (Madhoun, et al., 2012). For a short period of exposure may give dizziness, headache, loss of coordination, confusion and unconsciousness (Ogilvie, 2005).

Benzene is one of volatile organic compounds that greatly found at the car park which may produce through exhaust emission or evaporative emission of vehicles. At an enclosed car park, the effects will be more severe and aggressively attack the users and workers at the car park due to malfunction mechanical ventilation system, which leads volatile organic compounds, in particular, benzene to accumulate and give high concentrations. Benzene is the most dangerous volatile organic compounds, which can cause cancer to the users and workers of the car park. To maintain the concentrations of benzene below the allowable limit is very crucial to avoid cancer spreading among the car park users and workers. Workers will be more affected due to prolonged period of time, exposed to the benzene.

Malaysia does not implements any guidelines for benzene exposure limit. Hence, permissible exposure limit by U.S. Occupational Safety and Health Administration is taking into account with allowable 0.5 parts per million (ppm) of benzene in workplace at 8 hours' work-day and 40 hours' work-week (Madhoun, et al., 2012). Exposure limit for short-term airborne benzene, U.S. Occupational Safety and Health Administration has set up 5 ppm for 15 minutes (Madhoun, et al., 2012).

2.4 Particulate Matter 10 µm (PM_{10})

Particulate matter include solid and liquid droplet that vary in size (from a few nanometres in diameter to around 100 micrometres), which, it has been differentiate according to its size (Tomasevic, et al., 2013). Particulate matter 10 µm can be defined as fine and coarse particulate matter (California Environmental Protection Agency, 2007). Coarse particulate matter with aerodynamic diameter ranging from 2.5 to 10 µm, known as particulate matter 10 µm (PM_{10}) and fine particulate matter with aerodynamic diameter less than 2.5 µm, known as particulate matter 2.5 µm

(PM2.5) (Tomasevic, et al., 2013; Godish, 2004). Fine particles normally are formed through combustion or chemical processes at atmosphere and coarse particles are result of fugitive dust that may come from abrasion processes, dust from road paving, construction and quarrying activities (Charron & Harrison, 2005). Figure 5 shows range size of particulate matter 10 µm.

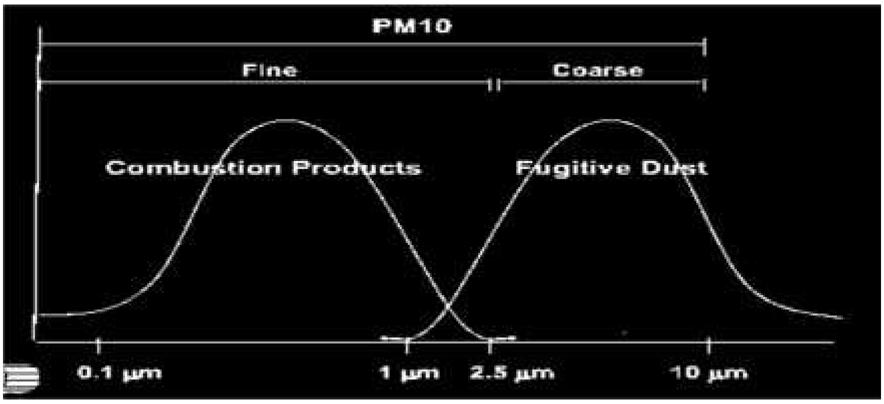

FIGURE 7: Range Size of Particulate Matter 10 µm

Different particulate matter will vary in density, morphology, physical properties and chemical composition (chemical properties will depend on its origin, how it was initially produced and following atmospheric history) (Tomasevic, et al., 2013). Chemical and physical compositions also depending on location, time of year, and weather (Salahudin, et al., 2013).

Larger and denser particulate matter with aerodynamic diameter ranging from 2.5 to 10 µm will settle out quickly within a few minutes, near the emission sources while, smaller and less dense particulate matter with aerodynamic diameter less than 2.5 µm remain suspended in the atmosphere from days to month and possible to be carried away to a distant regional (Tomasevic, et al., 2013).

The components of particulate matter (chemical composition) are predominantly comprise of black carbon, nitrate, ammonium, sulphate, aluminium, silicon, dust, salts, tire rubber and pollen but different source of particulate matter may have different component and proportion on different day and at different sites topography (Celis, et al., 2004). Shape of particulate matter is determined by the chemical composition and the formation processes, which its shape can be spheres, flat and layered, globular and irregular shape (Godish, 2004). In a study shown that, weather condition will affect the concentration of particulate matter (Feng & Wang, 2011). During summer and autumn, concentration of particulate matter will be low due to better diffusion and wet deposition, while during spring and winter, particulate matter concentrations increase due to stable inversion layer and low wind speed, cause the particulate matter will be trapped near to the ground and concentrations increase to high level (Feng & Wang, 2011). Since, Malaysia does not experience the four season, concentrations of coarse particulate matter will give higher value during dry condition due to increase for suspension of dust, soil and other particles.

2.4.1 Sources of Particulate Matter 10 µm

Particulate matter 10 µm can be classed into primary particulate matter and secondary particulate matter. Primary particulate matter 10 µm are particles that emitted directly into atmosphere either by natural sources or anthropogenic sources (Tomasevic, et al., 2013). Secondary particulate matter 10 µm formed by undergo homogeneous nucleation, transform from gas phase to particle phase with presence of sulphur dioxide, ammonia, volatile organic compounds, and nitrogen oxides act as precursor (World Health Organization, 2013; Air Quality Expert Group, 2005). Natural sources involve of volcanic eruptions, soil-dust uplift, sea-spray uplift, natural biomass burning fires, and biological material release whereas anthropogenic sources can be found through fugitive dust emissions (dust from road paving, passenger and agricultural vehicles, and building construction or demolition), fossil fuel combustion, and industrial emissions (World Health Organization, 2013; Jacobson, 2002). Table 11 represents major components of particulate matter 10 µm from selected sources.

TABLE 11: Sources and its Components of Particulate Matter
(Jacobson, 2002)

Components of Particulate Matter	**Sources**				
	Sea-Spray Emissions	*Soil-Dust Emissions*	*Volcanic Emissions*	*Fossil-Fuel Combustion for*	*Fossil-Fuel and Metal Combustion*

				Transportation and Energy	*for Industrial Processes*
Black Carbon			X	X	X
Organic Matter	X	X	X	X	X
Ammonium				X	X
Sodium	X	X	X		X
Calcium	X	X	X		X
Magnesium	X	X	X		X
Potassium	X	X	X		X
Sulfate	X	X	X	X	X
Nitrate					X
Chloride	X	X	X		X
Silicon		X	X	X	X
Aluminium		X	X	X	X
Iron		X	X	X	X

Vehicles may be responsible to the formation of particulate matter which contain a wide range of particle sizes from ultrafine particulate matter to coarse particulate matter (Charron & Harrison, 2005). Emission from vehicles will occur through exhaust emission, emission from abrasion processes and paved or unpaved roads dust re-suspension induced by the vehicle-generated turbulence. Exhaust emission is a product of fuel and lubricating oil burning while abrasion processes are from tyre wear emissions, brake linings, catalyst deterioration (Charron & Harrison, 2005). Vehicles with diesel engine will emit greater amount of particulate matter 10 μm than gasoline engine (Pundir, 2007).

2.4.2 Effects of Particulate Matter μm (PM_{10})

Particulate matter 10 μm are responsible for many health problems with chronic exposure. (Bari, et al., 2014) and tends to reduce the visibility (Feng & Wang, 2011). Breathing in coarse particulate matter for a short term with high concentrations can cause cardiovascular and respiratory diseases, and venous thromboembolic disease (Qiu, et al., 2012; Karakatsani, et al., 2012). Long term exposure is closely related to the effect of cognitive decline on older women (Weuve, et al., 2012). There will be a deposition of particulate matter in the upper way of bronchiolar region which, cause irritation, asthma attacks and lung inflammation (Bari, et al., 2014). Fine particulate matter has been examined as the greatest health problem due to the ability to penetrate deep into respiratory system and deposited at the wall of bronchi (Jimoda, 2012). Long term exposure to fine particulate matter, will result in loss of life expectancy (Pascal, et al., 2014).

According to Department of Environment Malaysia (2014), allowable exposure to particulate matter (PM10) for 24-hour average is 150 $\mu g/m^3$ and for 12-month average is 50 $\mu g/m^3$. World Health Organization (2005), has revised air quality guidelines for particulate matter as follows:

i. Fine particulate matter ($PM_{2.5}$)

Annual average: 10 $\mu g/m^3$
24-hour mean: 25 $\mu g/m^3$ (cannot be exceeded more than 3 days/year)

ii. Coarse particulate matter (PM_{10})

Annual average: 20 $\mu g/m^3$
24-hour mean: 50 $\mu g/m^3$

2.5 Relevant Case Study: Air Quality Inside Enclosed Car Park

There are a lots of ambient air quality studies are conducted all over the world. However, the study of air quality inside an enclosed car park still can be considered as minimal. Due to rapid urbanization, numerous type buildings are constructed and the development, leading to shortage of land especially at city area and the price is also greatly higher. The stable economy, give an advantage to each individuals to have their own vehicles and the growth number of vehicles, have given high demand for parking facilities. Because land surface has been utilized to its full value, multi-storey enclosed underground car parks are increasingly popular and cause poor air quality in underground car parks. Malaysia also implement this approach, construct more multi-storey enclosed car park in order to cater the problem of great parking demand in recent years.

Generally, the assessment of air quality inside an enclosed car park has been done at some established area such as Athens, Wuhan and Hong Kong because those area having several multi-storey enclosed car park. The development of Kuala Lumpur City with built up of multi-storey car parks, give awareness to the researcher from Malaysia, and start to conduct air quality study inside enclosed car park. The number of studies recorded in Malaysia are still low.

In Athens, volatile organic compounds pollutants that emitted by vehicles (through the exhaust emission of fuel and evaporative emission of fuel) is examined at enclosed car park. At the enclosed car park, the concentrations of volatile organic compounds, which mainly comprise of benzene, toluene, ethylbenzene and xylene (BTEX) are significantly elevated because they can be emitted by both approaches exhaust emission and evaporative emission, either vehicles in motion or in stationary. The emission of volatile organic compound, which is group of BTEX become a great concern due to their toxicity and benzene is carcinogenic that possible to cause cancer.

The concentrations of BTEX are collected for 6 hour continuously by using personal diffusive sampler (SKC 575-001), it is placed at stationary points with height of breathing zone. Diffusive sampler then desorbed with 2 ml of carbon disulphide. It need to be shake for 1 hour, the extraction of 5 µl is injected into Perkin Elmer Sigma 200 gas chromatograph equipped with a split-spitless injector and a flame ionization detector.

From the result obtained, among the group of BTEX, benzene recorded for average 6 hour as the highest concentration with mean 405 µg m-3, following by toluene with mean 338 µg m-3, while the mean concentrations of m+p xylene, o-xylene and ethylbenzene are 257 µg m-3, 104 µg m-3 and 98 µg m-3 respectively. The mean of summation BTEX is 1269 µg m-3. NIOSH has established allowable limit for benzene with concentrations 320 µg m-3. The mean concentrations of benzene from this enclosed car park is exceeded the NIOSH limit.

The concentrations of BTEX in an enclosed car park is greatly depends on car density and ventilation rate of the building. Sometime, enclosed car park with lower density will give higher concentrations of BTEX compare to enclosed car park with high density of car. This situation may occur due to ventilation differences between two enclosed car parks. It can be expected that the mechanical ventilation system at car park with lower density is not efficient to prevent the build-up of BTEX inside the car park. The temperature plays an important role to the concentrations level of BTEX, the evaporation of fuel will be more vigorously as the temperature rises during the day.

In china, due to health concern to the users and workers of enclosed car park, several studies on concentrations level of pollutants are been carried out. One of the pollutants that significantly important to investigate is particulate matter 10 µm because from other studies have shown that particulate matter is more toxic compare to carbon monoxide. At enclosed car park the effects will be worse than at ambient air. A sampling of particulate matter 10 µm has been conducted at an underground car park of a public complex, situated in Wuchang District, Wuhan, which is the biggest metropolitan city in central China, with a total residential population of more than 8 million. The underground car park has floor area of about 10,000 m^2 with 256 parking bays.

The samples were collected at entrance and exit of this enclosed car park. The sampling period is from 8 May 2011 until 26 May 2011, which is about 19 days start from 0700 hour until 2100 hour. This study has been conducted by using gravimetric analysis, filters are equilibrated in a desiccator before and after sampling, at 20 ◦C – 23 ◦C of air conditioned room for 48 hours, and then electronic microbalance has been used to weigh the filters with 0.1 mg sensitivity to define the particulate matter mass. After 1 hour, filters are weighed again and difference in-weighing should be less than 0.5 mg. Blank filters are used to identify possible gravimetric bias due to filter handling during and/or after sampling. After gravimetric analysis, the concentrations of particulate matter 10 µm is determined through some process. From the result obtained, it shows that 14 hour average concentration particulate matter 10 µm at exit (ranges from 50.6 µg/m^3 to 442.4 µg/m^3) higher than at the entrance (ranges from 36.4 µg/m^3 to 201.8 µg/m^3).

From the 14 hour calculated mean, particulate matter 10 µm at exit it gives 234.4 µg/m^3, this value is compare to indoor air quality standard china because the standard for underground car park is not available. The mean value is exceeded by 56% of indoor air quality standard china, which its daily standard is 150 µg/m^3. However, this sampling is conducted for 14 hour, if the sampling is conducted for 24 hour, the average concentration particulate matter 10 µm might be slightly lower due to vehicle flow will be reduced after 0900 hour. 14 hour average concentration particulate matter 10 µm at exit higher than at the entrance because dust re-suspension, wear of tyre and brake linings occurred more frequent at the exit. Road surface at the exit also dirtier than the entrance. All these factors are contribute to the formation particulate matter 10 µm

Comparison between concentrations particulate matter 10 µm between at underground car park and ambient air is conducted. Data of particulate matter 10 is collected at nearby monitoring station around 1.5 km northwest of the underground car park. Apparently, the concentrations of particulate matter 10 µm at underground car park is higher than at the ambient air. This is happen, might be due to cars frequently accelerated, decelerated and stopped, which it generates coarse particle emission from non-exhaust source such as tyre wear and brake wear.

However, in Malaysia, lack of studies and researches conducted to examine the particulate matter 10 µm at enclosed car park. It is significant to conduct a study at enclosed car park in Malaysia, as a result, an enclosed park at Kuala Lumpur City has been chosen for the sampling. This sampling is conducted in 10 days duration. Daily collection which is 24-h real time data. The concentrations of particulate matter 10 µm that will be obtained are predicted to be vary from the sampling at Wuhan, China. This is because the difference in numbers of parking bays at the sampling location, at level P2 enclosed car park at Kuala Lumpur with amount 1363 are higher than enclosed car park at Wuhan, China with 256 parking bays. From the number of parking bays recorded, the estimated vehicles entering and leaving the enclosed car park at Kuala Lumpur is greater, as a result, the will be more vehicles moving inside and then accelerated, decelerated and stopped, which it leads to the formation of particulate matter 10 μm from tyre wear and brake wear. The concentrations of particulate matter 10 μm will be slightly affected by the temperature and humidity inside the enclosed car park. The effectiveness of mechanical ventilation system also influenced the concentrations result. The data will be automatically collected by AQM60, which ensure accurate result without involving any external factors which can be biased to the result.

A study of Energy, environmental and economic analysis of the ventilation system of enclosed parking garages: Discrepancies with the current regulations has been conducted at underground car park of Madrid’s major shopping streets by Lopez, et al. (2014). This study has shown the relationship between the effectiveness of ventilation system and air quality at enclosed car park.

The aim of this study is to achieve greater efficiency in the ventilation systems of enclosed parking garages. An accurate calculation of the air flow (contains pollutants) is required to design high efficiency ventilation system. Profound study on the calculation, has produce high efficiency of ventilation system. From the result obtained, it has proved that efficient ventilation system will improve the air quality, since harmful pollutants emit by vehicles has been removed successfully. It is crucial to ensure enclosed car park having a good air quality, because the presence of pollutants from vehicles beyond the allowable limit are very dangerous to human health.

CHAPTER 3

METHODOLOGY

3.1 Location of Sampling

This sampling will be conducted at one of high prestige enclosed car park of multipurpose building situated at Kuala Lumpur City, Peninsular Malaysia. This multipurpose building consists of shopping mall and office buildings. It is designed with five-storey enclosed car park. There are 5400 parking bays in total. The built up of this car park is to accommodate vehicles for visitors and employees at this building. Figure 8 shows the map of sampling location. The exact location of the sampling will be at level 2 (P2), beside an office of the car park at basement, which consist of 1363 bays of car park.

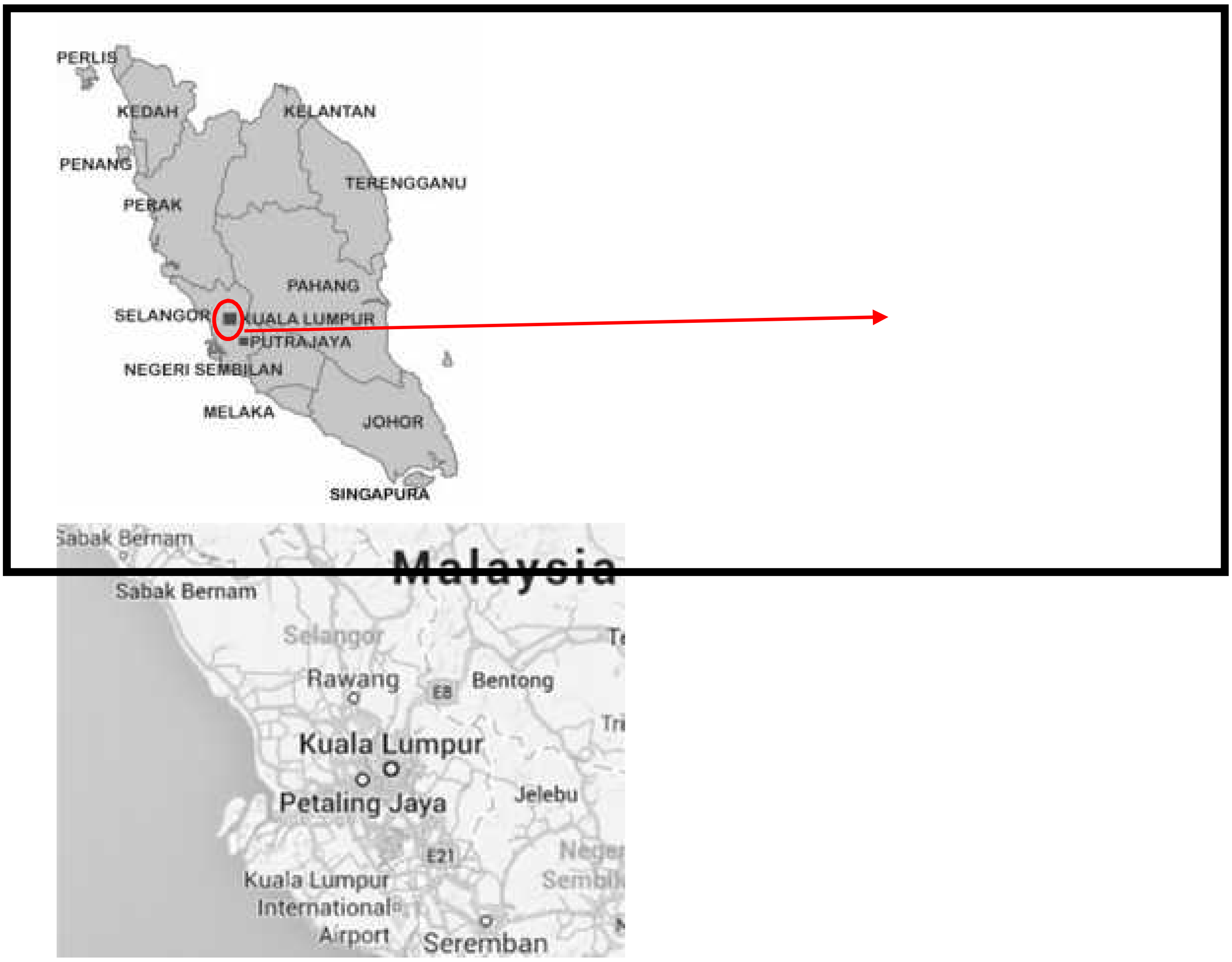

FIGURE 8: Map of Sampling Location

Kuala Lumpur having tropical rainforest climate, which experiences hot and humid weather. Kuala Lumpur receives rainfall at any time with raining 200 days of the year. Throughout the year, temperature in Kuala Lumpur, Malaysia is fairly stable with lowest average is 22 °C and highest average recorded 32 °C. Kuala Lumpur is constantly hot all through the year. Figure 9 illustrates the high and low temperature for Kuala Lumpur.

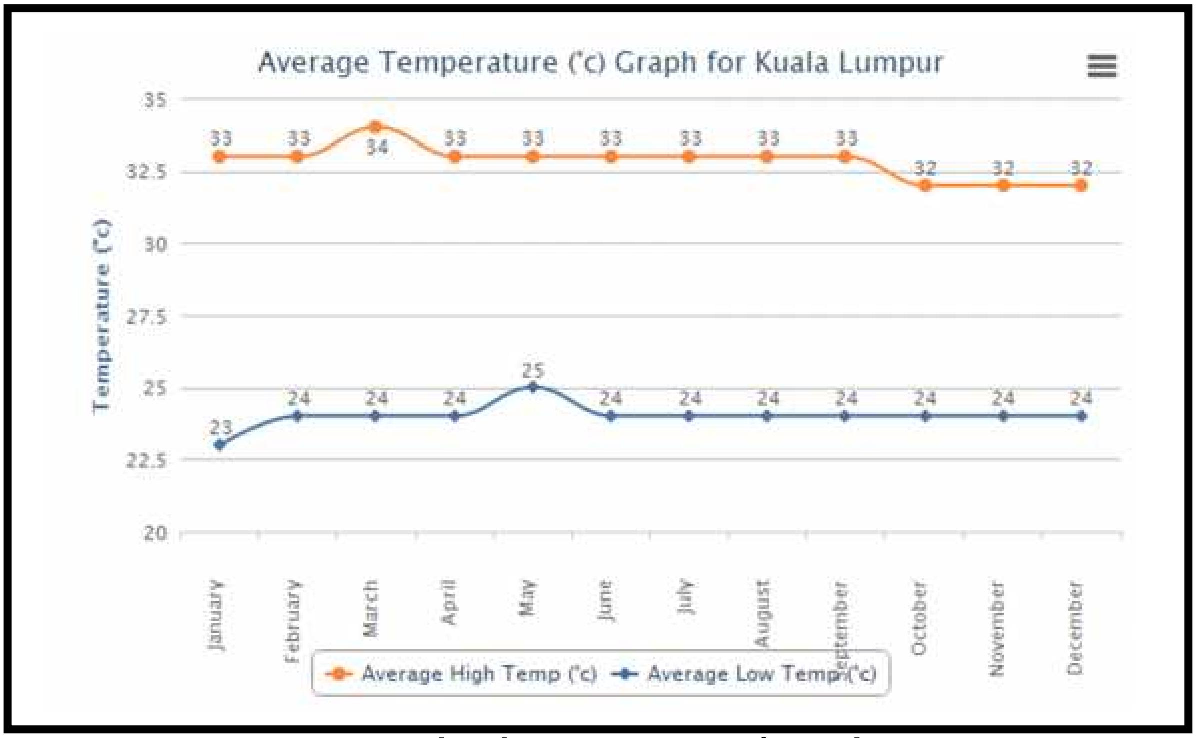

FIGURE 9: High and Low Temperature for Kuala Lumpur.

3.2 Samples Data

There are two samples data are chosen to be collected at the enclosed car park. There are carbon dioxide and particulate matter 10 µm. Samples collection is 24-h real time data for 10 days duration.

3.3 AQM60 Environmental Station

The Aeroqual AQM60 Environmental Station is a custom-built ambient air quality instrument. This instrument is specially designed to measure common air pollutants such as carbon dioxide, carbon monoxide, sulphur dioxide, nitrogen dioxide, ozone, particulate matter 10 µm (PM10, PM2.5), volatile organic compounds, non-methane hydrocarbons, hydrogen sulphide and meteorological parameters include, temperature, humidity, wind speed and direction. It collects data for two minutes interval.

Aeroqual's AQM 60 Air Quality Station serves its purpose as air quality monitoring network and it is compact and designed for low-cost and easy deployment. The AQM 60 station compromises long term quantitative, time integrated atmosphere measurement with excellent correlation to reference methods. Conventional air quality stations has some drawbacks such as power-hungry, costly, large and need a close calibration and maintenance program. Due to these reasons, it is become not relevant for micro-scale and high-density monitoring. Figure 10 shows the component of AQM 60 Air Quality Station.

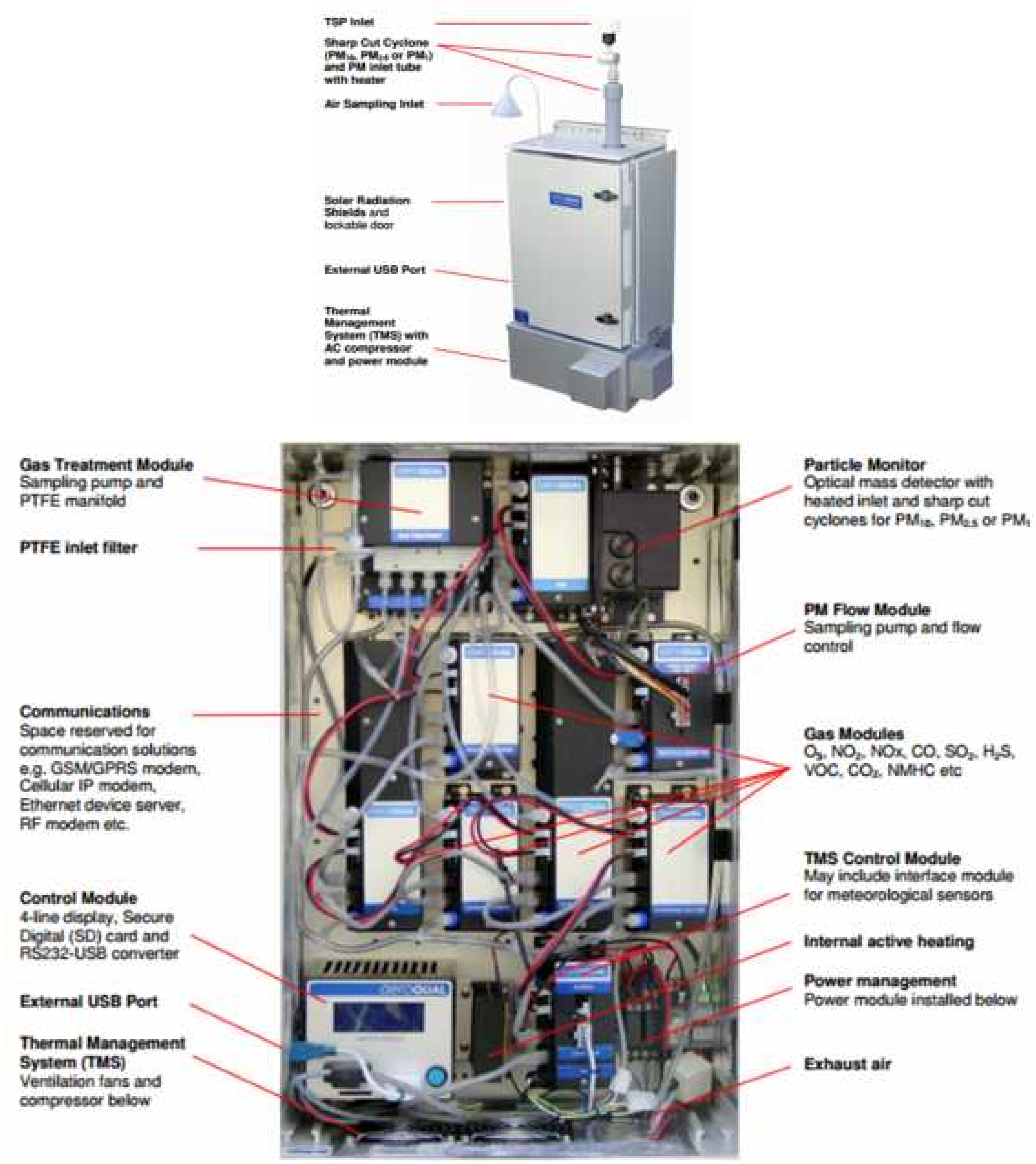

FIGURE 10: Component of AQM 60 Air Quality Station

3.3.1 How to Operate AQM60 Environmental Station

i. Unpack AQM and the packaging is saved for transport purpose in the future.
ii. Conduct an inspection on AQM to ensure AQM is free from damage that might be occurred during transport.
iii. Install power lead into power supply module.
iv. If necessary, fit mounting hardware.
v. Assemble peripheral sensors such as wind speed or direction sensors, PM inlet etc.
vi. Insert SD data card upside down correctly into slot on control module
vii. Press blue power button on control module to turn on AQM.
viii. Set up for AQM
    a. Connect AQM control module and computer by using USB cable.

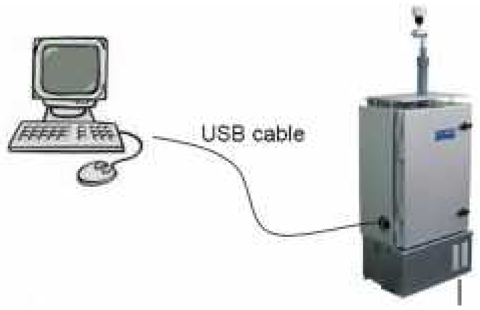

FIGURE 11: USB Cable Connects AQM Control Module with Computer

    b. Launch AQM PC software.
    c. Click Setup → Com port to select correct com port on PC.
    (Note the USB port on AQM is a RS232 adaptor with a unique Com Port number)
    d. Click File → Search Monitor. Automatically, computer will find and connect to AQM.
    e. Click Tools → Update Real Time Clock (The AQM clock will synchronise with the computer date and time)

ix. Start data logging to ensure sensor communication and operation is correct.
    a. Click Data → Table → Real Time to launch real time data table.
    b. Click File → Start Data logging. In Real Time Table, data will be displayed.

3.4 Traffic Flow

The trend of vehicle entering and leaving the car park is observed.

3.5 Analysis by Time Series Model

Collected data from AQM60, which emphasis on carbon dioxide and particulate matter 10 µm, will be analysed by using time series model. This analysis also will be used to observe the relationship between number of vehicles and concentrations of pollutants such as on sulphur dioxide, volatile organic compounds and particulate matter 10 µm. Time series model is a collection of observations of well-defined data items obtained through repeated measurements over time. The data will be collected for every 2 minute interval for 10 days duration for 24-h real time data. The data is tabulated and presented in the form of time series model by taking an hourly average by using Microsoft Excel and the data is analysed according to weekdays (except Friday), Friday and weekend.

The main aim of time series model is to describe movement history of a particular variable in time. Time series model of air pollution environmental levels involves the identification of long-term variation in the mean (trend) and of cyclical or periodic components. Through this analysis, trend and pattern of carbon dioxide and particulate matter 10 µm concentrations can be observed and relationship between number of vehicles and concentrations of pollutants such as on sulphur dioxide, volatile organic compounds and particulate matter 10 µm in accordance to different time and different type of days weekdays (except Friday), Friday and weekend. Time series model is a useful tool for better understanding of cause and effect relationships in environmental pollution. A reliable statistics and characteristics will be produced this analysis.

3.6 Compare Concentrations of Pollutants with Standard Guidelines

Compare concentrations of each sample that obtained inside the enclosed car park with Standard Guidelines. If concentrations higher than limit by Standard Guidelines, meaning the air has been polluted and the exposure will be harmful.

3.7 Key Milestone

The project milestone for Final Year Project (FYP) 1 is presented in Table 12.

TABLE 12: Milestone FYP 1

No	Activities	Duration													
		2014													
		MAY		JUN				JULY					AUG		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection Project Title	●													
	1. Survey Project Title														
2	Project Confirmation		●												
	1. Comfirmed by Supervisor & Coordinator														
	2. Discuss with Supervisor on the Project Title before start works														
3	Submission of Extended Proposal						●								
	1. Collect and Identify Relevant Books, Research Papers and Journals														
	2. Understand Problem Statement														
	3. Identify Objectives & Scope of Study														
	4. Carry out Comprehensive Literature Review														
	5. Methodology														
	6. Prepare Extended Proposal														
4	Amendment of Extended Proposal									●					
5	Proposal Defence									●					
	1. Presentation Preparation.														
6	Submission Draft Interim Report													●	
	1. Improve Extended Proposal from Comments Given by Supervisor and Internal during Presentation														
7	Submission of Interim Report														●

	Work Done
	Work Delay
●	Target Completion (Milestone)
	Progress

The project milestone for Final Year Project (FYP) 2 is presented in Table 13.

TABLE 13: Milestone FYP 2

No	Activities	Duration													
		2014													
		SEPT		OCT				NOV				DEC			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Pregress Report								●						
	1. Research Work Continues														
	2. Set up the equipment														
	3. Collect data														
	4. Analyse Data														
2	Pre-SEDEX										●				
	1. Improve the Project according Comments on Progress Report														
	2. Poster Preparation														
	3. Discuss with Supervisor on the Poster														
3	Submission of Draft Report											●			
	1. Prepare Draft Report by Taking Into Accounts Comments and Recommendation from Examiners during Poster Presentation														
	2. Discuss with Supervisor on Improving Data Analysis														
4	Submission of Dissertation (Soft Bound)												●		
	1. Amendment of Draft Report														
5	Submission of Technical Paper												●		
	1. Prepare Technical Paper by Putting Important Elements from the Dissertation														
6	Oral Presentation (VIVA)													●	
7	Submission of Dissertation														●

	Work Done
	Work Delay
●	Target Completion (Milestone)
	Progress

3.8 Gantt Chart

The project Gantt chart for Final Year Project (FYP) 1 is presented in Table 14.

TABLE 14: Gantt chart FYP 1

No	Progress	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■	■												
2	Preliminary Research Work		■	■	■	■									
3	Submission of Extended Proposal						●								
4	Proposal Defence								■	■ ●					
5	Project Work Continues										■	■	■		
6	Submission of Interim Draft Report													●	
7	Submission of Interim Report														●

■ Process ● Suggested Milestone

The project Gantt chart for Final Year Project (FYP) 1 is presented in Table 15.

TABLE 15: Gantt chart FYP 2

No	Progress	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continues	■	■	■	■	■	■	■							
2	Submission of Progress Report								●						
3	Project Work Continues								■	■	■	■	■		
4	Pre-SEDEX										●				
5	Submission of Draft Report											●			
6	Submission of Dissertation (Soft Bound)												●		
7	Submission of Technical Paper												●		
8	Oral Presentation (VIVA)														●
9	Submission Dissertation														●

Process Suggested Milestone

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

Analysis on the concentration of air pollutants for particulate matter 10 μm and carbon dioxide is conducted based on 10 days of sampling which is, started from 6 November 2014 until 17 November 2014. The data are collected for every 2 minutes interval for 24 hours real time. There are 7200 numbers of data has been collected for each pollutants for 10 days of sampling. The sampling is carried out at the same place for 10 days, at one of high prestige multi-layer car park in Kuala Lumpur. The equipment was placed beside an office at this car park level. Pattern of pollutants' concentration has been analysed. Building of this car park consists of offices and shopping complex.

The raw data are processed into hourly average, to be presented in form of time series model by using Microsoft Excel. The results of sampling are categorized according to weekdays (except Friday), Friday and Weekend. From the graph obtained, analysis can be done based on the trend of concentration for each category and comparison between concentration on weekdays (except Friday), Friday and weekend can be evaluated. This result of sampling are divide into three categories due to different vehicle's trend for these three day. Vehicle is an important aspect to be considered because it is the main contributor for pollutants emission to be measured.

4.2 Concentration of Particulate Matter 10 µm on Weekdays (Except Friday)

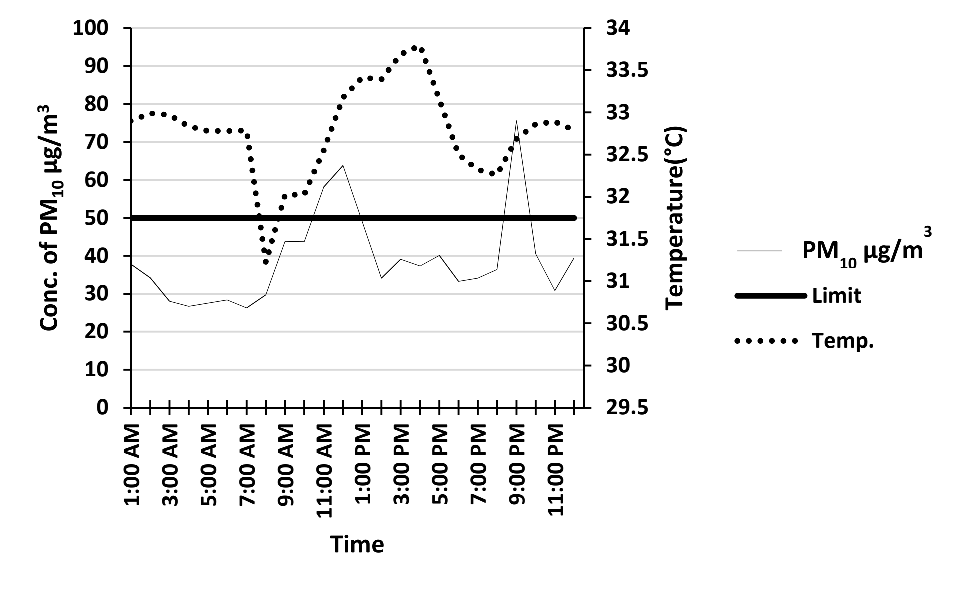

Figure 31: Concentration of Particulate Matter 10 µm and Temperature VS Time on Weekdays (Except Friday)

Figure 11 illustrates the concentration of particulate matter 10 µm and temperature on weekdays (except Friday). For particulate matter 10 µm, temperature does not give significant effects to rise and drop of its concentration. After some observation, the fluctuation of particulate matter 10 µm is mainly cause by the movement of vehicles inside the car park.

At 1:00 a.m. the concentration of particulate matter 10 µm is 37.82 $\mu g/m^3$ and decreased to 34.20 $\mu g/m^3$ at 2:00 a.m. Then, the concentration is gradually decrease until 5:00 a.m. which is, the concentration become 27.50 $\mu g/m^3$. At 6:00 a.m. the concentration of particulate matter 10 µm, shows a little increment to 28.40 $\mu g/m^3$ and drop again to 26.26 $\mu g/m^3$ at 7:00 a.m. The concentration of particulate matter 10 µm start increasing again at 8:00 a.m. with value of 29.70 $\mu g/m^3$ and keep growing tremendously at 9:00 am, which is 43.81 $\mu g/m^3$ concentration is achieved.

At 10:00 a.m. concentration of particulate matter 10 µm is drop marginally to 43.69 µg/m^3. Concentration of particulate matter 10 µm at 11:00 a.m. shows great increment to 58.11 µg/m^3 and at noon, 12:00 p.m., its achieved peak concentration of particulate matter 10 µm with 63.77 µg/m^3. This is the highest value recorded during day. However, concentration of particulate matter 10 µm is continually decrease until 2:00 p.m. and the variance is substantial which is, the concentration at this hour is 34.14 µg/m^3. There is a minor increment at 3:00 p.m. and the value recorded is 39.06 µg/m^3. After 3:00 p.m. until 6:00 p.m., there is fluctuation of concentration but the difference is small. At 6:00 p.m. the concentration is 33.30 µg/m^3. From 6:00 p.m. to 8.00 p.m., it shows the concentration is gradually increased and achieved 36.36 µg/m^3. After that, it has increased extremely and at 9:00 p.m., it reached the peak value for the whole day of 75.56 µg/m^3. At 10:00 p.m., the concentration is abruptly drop and it became 40.54 µg/m^3 and continuously decrease until 30.8 µg/m^3 at 11:00 p.m.

4.2.1 Analysis on Concentration of Particulate Matter 10 µm on Weekdays

According to Malaysia Ambient Air Quality Guidelines, for particulate matter 10 µm, allowable limit for exposure 12 month is 50 µg/m^3. So, when the concentration of particulate matter 10 µm exceed this allowable limit, the air is considered polluted by particulate matter 10 µm and it might cause health implication to employees and visitors.

From the overall graph in Figure 11, it can be observed that, the concentration of particulate matter 10 µm at 1:00 a.m. is 37.80 µg/m^3. Even though, at this time, number of vehicles entering and leaving the enclosed car park is lower or none, but this concentration value is influenced by the trapped particulate matter 10 µm and accumulated that released by vehicles at previous hour. There is a big possibility that this car park encounter with ventilation system problem. As a result, the pollutant cannot be removed effectively. However, from 1:00 a.m. until 7:00 a.m., the graph shows reduction in its concentration as compare to initial concentration at 1:00 a.m. and finally it achieved the lowest concentration for the whole day at 7:00 a.m. with 26.26 µg/m^3. This happen due to negligible number of vehicles entering and leaving the car park from 1:00 a.m. until 7:00 a.m., and along this period trapped particulate matter 10 µm has been removed out to the outside environment. This explained the reason of the lowest concentration at 7:00 a.m. From 7:00 a.m. to 9:00 a.m., the concentration of particulate matter 10 µm is increased significantly to 43.8 $\mu g/m^3$. In Malaysia, most companies will start operating in between 7:00 a.m. to 9:00 a.m. and for the shopping complex employees, they start working at 10:00 a.m. So, it can be said that, the employees' vehicles entering the car park from 7:00 a.m. to 9:00 a.m. At 11:00 a.m. the concentration is increased to 58.11 $\mu g/m^3$ and this value is influenced by visitors' vehicles that visit this shopping complex. At noon, the highest concentration recorded is at 12:00 p.m., 63.77 $\mu g/m^3$, due to lunch hour. At this time, there will be more visitors coming to enjoy their lunch inside this building and also the employees' from this building might have their lunch at outside restaurant or at home. The movement of vehicles become active at this time, which contribute to the increment concentration of particulate matter 10 µm. After that, concentration of particulate matter 10 µm, decrease to 49.03 $\mu g/m^3$ and 34.14 $\mu g/m^3$ at 1:00 p.m. and 2:00 p.m. respectively. This is happen due to vehicles entering and leaving the car park as not much as at 12:00 p.m. Most companies in Malaysia, their lunch break finish at 2:00 p.m., the abruptly drop concentration at 2:00 p.m. is due to visitors already leave that building and employees at this building reach here before 2:00 p.m. From 2:00 p.m. to 6.00 p.m., the fluctuation of concentration occurred but the difference between drop and rise is small. The concentration within this time is mainly affected by visitors that visit this building. From the graph, it shows the concentration drop at 6:00 p.m., 33.30 $\mu g/m^3$ and it is started to increase gradually until 8:00 p.m. 36.36 $\mu g/m^3$. After that, from 8:00 p.m. until 9:00 p.m. the concentration of particulate matter 10 µm is increase tremendously and reach the peak value for the whole day, 75.57 $\mu g/m^3$. The increment within 6:00 p.m. to 9:00 p.m. is caused by two factors, firstly due to employees are went back home at this time which is, some of them willing to stay at office until night to avoid traffic jam. Secondly, after working hours, there will be many visitors visit this place, to have dinner here or buy their needs. Peak concentration at 9:00 p.m. shows, at that particular time is the most active moment for vehicles entering and leaving the car park. As can be seen from the graph at 10:00, the concentration is low due visitors' vehicles already leave this place since the shopping complex closed at 10:00 p.m.

From 11:00 p.m. to 12:00 a.m. the concentration is slightly increase due to employees of the shopping complex leave this building at this time.

4.3 Concentration of Particulate Matter 10 μm on Friday

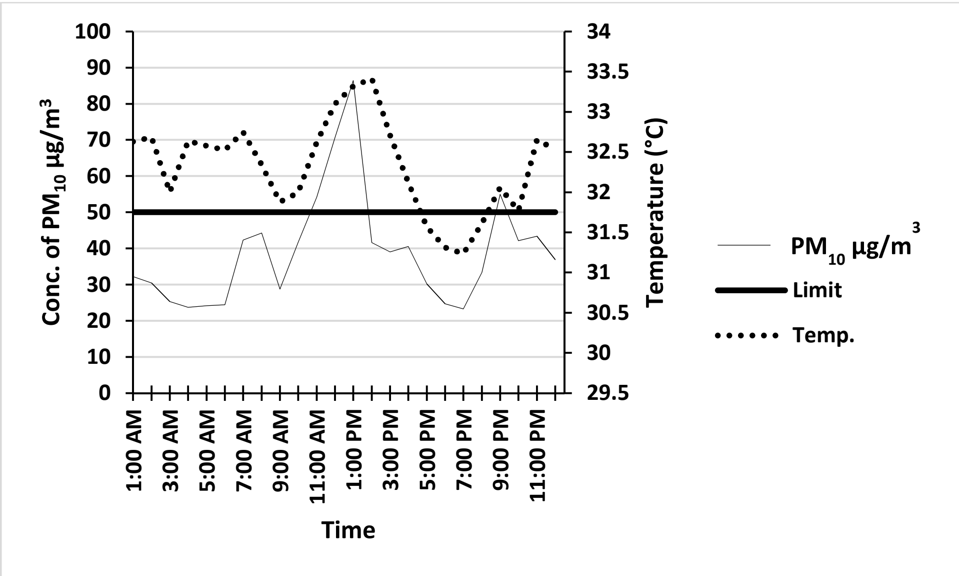

Figure 12: Concentration of Particulate Matter 10 µm and Temperature VS Time on Friday

Figure 12 illustrates the concentration of particulate matter 10 µm and temperature on Friday. At 1:00 a.m. the concentration of particulate matter 10 µm is 49.67 µg/m^3. After that, the concentration is continually decrease until 23.70 µg/m^3 at 4:00 a.m. From 4:00 a.m. to 5:00 a.m. the concentration is rise to 36.82 µg/m^3 and drop again at 6:00 a.m. with value of 24.43 µg/m^3. At 7:00 a.m., the graphs shows significant increment to 42.33 µg/m^3 and slightly increase to 44.31 µg/m^3 at 8:00 p.m. However, from 8:00 a.m. to 9:00 a.m., concentration of particulate matter 10 µm decline to 28.80 µg/m^3. Then, it is started to increase continuously and reach extreme value of 86.46 µg/m^3 at 1:00 p.m. At 2:00 p.m. the concentration is abruptly drop to 41.59 µg/m^3. Once again, it decrease but marginally to 39.05 µg/m^3 at 3:00 p.m. The concentration of particulate matter 10 µm is slightly rise to 40.52 µg/m^3 at 4:00 p.m.

From 4:00 p.m. to 7:00 p.m. the concentration is gradually decrease to 23.39 µg/m^3. Then, the graph slowly increase to 33.40 µg/m^3 at 8:00 p.m. and rapidly rise to 54.95 µg/m^3 at 9:00 p.m. At 10:00 p.m. the concentration decline to 42.13 µg/m^3 and growth a little to 43.41 µg/m^3 at 11:00 p.m. From 11:00 p.m. to 12 a.m. it is decrease to 36.96 µg/m^3.

4.3.1 Analysis on Concentration of Particulate Matter 10 µm on Friday

According to Malaysia Ambient Air Quality Guidelines, for particulate matter 10 µm, allowable limit for exposure 12 month is 50 µg/m^3. So, when the concentration of particulate matter 10 µm exceed this allowable limit, the air is considered polluted by particulate matter 10 µm and it might cause health implication to employees and visitors.

Friday is also recognized as weekday, but in Malaysia, working hours during Friday is quite different which is, it will give different trend of concentration for particulate matter 10 µm. From the overall graph in Figure 12, it can be observed that, the concentration of particulate matter 10 µm at 1:00 a.m. is 32.26 µg/m^3, even though, at this time, number of vehicles entering and leaving the enclosed car park is lower or none, but the concentration given is due the trapped particulate matter 10 µm and accumulated that released by vehicles at previous hour. This is happen caused by ventilation system problem. Consequently, particulate matter 10 µm cannot diffuse completely in a short time to the outside environment and it will stay for few hours. Then, by time, the decline of concentration can be observed until 6:00 a.m. with value of 24.42 µg/m^3 because along the period trapped particulate matter 10 µm has been removed out gradually. However, from 6:00 a.m. to 7:00 a.m. the concentration increase rapidly and it reach 42.33 µg/m^3. This shows that vehicles start entering the car park. In Malaysia, most companies will start operating in between 7:00 a.m. to 9:00 a.m., based on the information received from trusted sources, companies in this building applied flexible working hours. This is means, employees can choose either start work early as 7:00 a.m. or latest by 9:00 a.m. On Friday, employees mostly prefer to start their work earlier, which is, they will arrive this car park before 7:00

a.m. This is the reason for the increment of concentration particulate matter 10 µm and for other weekdays, usually, employees start entering the car park at 7:00 a.m. There some factors, employees come earlier on Friday compare to other weekdays, this is because Friday is the last day before weekend, and some employees need more time to settle down everything related to work before enjoying their holiday. Another factor, for some reason, employees want to back home earlier on the last of working days. At 8:00 a.m. the concentration is slightly increase to 44.31 µg/m^3 and this concentration is also contribute by the employees' vehicles. However, the concentration of particulate matter 10 µm is drop to 28.79 µg/m^3 at 9:00 a.m. This is because most of the employees has come earlier. From 9:00 a.m. to 10:00 a.m., the graph rise to 41.66 µg/m^3. At this time, employees for shopping complex and early visitors start coming, since the shopping start operating at 10:00 a.m. But mostly, the concentration is contribute by employees for shopping complex. At 11:00 a.m. the concentration is increased to 54.15 µg/m^3 and this value is influenced by visitors' vehicles that visit this shopping complex. At noon, the concentration become extremely higher compare on weekdays, at 12:00 p.m. the concentration recorded is 70.63 µg/m^3. This is due to longer lunch break for employees. At this time, there will be more visitors coming to enjoy their lunch inside this building and also the employees' from this building might have their lunch at outside restaurant or at home. The movement of vehicles become active at this time, which contribute to the increment concentration of particulate matter 10 µm. After that, the graph drop abruptly to 41.59 µg/m^3 at 2:00 p.m. due to less movement of vehicles inside the car park. Then, it decrease again at 3:00 p.m. with concentration of 39.05 µg/m^3. At 4:00 p.m. the graph shows minor increment and this increment might cause by the some employees leaving their workplace at 4:00 p.m. for those who come at 7:00 a.m. From 4:00 p.m. to 7:00 p.m. the graph is gradually decrease to 23.29 µg/m^3, this is due to the visitor entering and leaving this car park become lesser within this time. Then, the concentration of particulate matter 10 µm increase gradually until 8:00 p.m. and the concentration recorded is 33.46 µg/m^3. After that, from 8:00 p.m. until 9:00 p.m. the concentration of particulate matter 10 µm is increase tremendously and reach the value of 54.95 µg/m^3. The increment within 6:00 p.m. to 9:00 p.m. is caused by two factors, firstly due to employees are went back home at this time which is, some of them willing to stay at office until night to avoid traffic jam.

Secondly, after working hours, there will be many visitors visit this place, to have dinner here or buy their needs. As can be seen from the graph at 10:00, the concentration is low due visitors' vehicles already leave this place since the shopping complex closed at 10:00 p.m. At 11:00 p.m. concentration of particulate matter 10 µm rise to 43.41 µg/m^3 and this increasing is contributed by employees of the shopping complex that leaving car park at this time.

4.4 Concentration of Particulate Matter 10 µm on Weekend

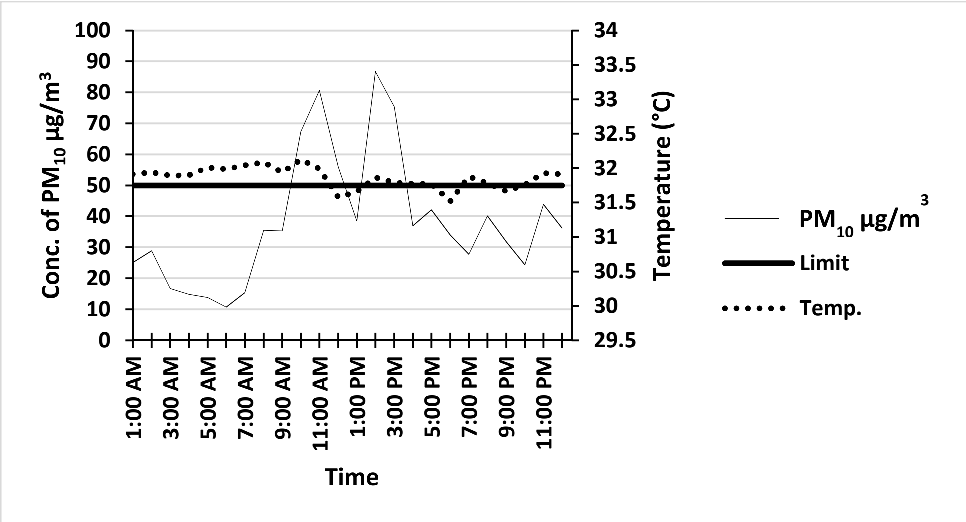

Figure 13: Concentration of Particulate Matter 10 µm and Temperature VS Time on Weekend

Figure 13 illustrates the concentration of particulate matter 10 µm and temperature on weekend. At 1:00 a.m. the concentration is 25.12 µg/m^3 and small increment occurred at 2:00 p.m. with the value of 28.86 µg/m^3. After that, the concentration drop to 16.72 µg/m^3 at 3:00 p.m. From 3:00 p.m. to 6:00 p.m. concentration particulate matter 10 µm is gradually decreased to 10.68 µg/m^3. At 7:00 a.m. the concentration has slightly increase to 15.34 µg/m^3. From 7:00 a.m. to 8:00 a.m. concentration particulate matter 10 µm is tremendously rise with value of 35.48 µg/m^3. The concentration is increased marginally to 35.32 µg/m^3 at 9:00 a.m. From

9:00 a.m. to 10:00 a.m., the graph shows a great increment of concentration of particulate matter 10 µm, it gives value of 67.30 µg/m^3. Then, it is continually increase to 80.69 µg/m^3 at 11:00 a.m. At 12:00 p.m., the concentration decline to 55.99 µg/m^3 and drop to 38.49 µg/m^3 at 1:00 p.m. From 1:00 p.m. to 2:00 p.m., the concentration growth rapidly and reach peak concentration of 86.70 µg/m^3. After that, the concentration particulate matter 10 µm drop to 75.41 µg/m^3 and 36.91 µg/m^3 at 3:00 p.m. and 4:00 p.m. respectively. After abruptly decline, the concentration is slowly growth to 42.14 µg/m^3 at 5:00 p.m. but it started to fall again at 6:00 p.m. with concentration of 33.92 µg/m^3. At 7:00 p.m., the concentration is continuously decrease until 27.73 µg/m^3. From 7:00 p.m. to 8:00 p.m., as can be seen from the graph, the concentration is slightly increase to 40.16 µg/m^3. Then, from 8:00 p.m. to 10:00 p.m., the graph is steadily decrease to 24.37 µg/m^3. At 11:00 p.m., concentration of particulate matter 10 µm shows an increment to 43.88 µg/m^3 and drop to 36.25 µg/m^3 at 12:00 a.m.

4.4.1 Analysis on Concentration of Particulate Matter 10 µm on Weekend

According to Malaysia Ambient Air Quality Guidelines, for particulate matter 10 µm, allowable limit for exposure 12 month is 50 µg/m^3. So, when the concentration of particulate matter 10 µm exceed this allowable limit, the air is considered polluted by particulate matter 10 µm and it might cause health implication to employees and visitors.

From the overall graph in Figure 13, it can be seen that at from 1:00 a.m. until 6:00 a.m., there is the presence of particulate matter 10 µm. Even though, at this time, lower or no vehicles entering and leaving this car park. But this value given by trapped particulate matter 10 µm at previous hour. The ventilation in this car park cannot remove out particulate matter 10 µm completely at short period. Ineffective ventilation has caused particulate matter 10 µm to stay longer inside the car park. However, during weekend, the concentration recorded between this periods is lower than on weekdays. This concentration value is influenced by movement of vehicles at previous night, which is, it might be less. From 6:00 a.m. to 9:00 a.m. the graph shows an increment which is from 10.68 µg/m^3 to 35.32 µg/m^3. It illustrates that, there is vehicles movement within this periods due to some employees might come to the office on weekend to settle their urgent works, but the value does not exceed the value on weekdays. From 9:00 a.m. to 10:00 a.m., the concentration of particulate matter 10 µm is increased significantly to 67.3 $\mu g/m^3$. At this time, employees for shopping complex and early visitors start coming, since the shopping start operating at 10:00 a.m. But mostly, the concentration is contribute by employees for the shopping complex. From this graph, it can be seen that, there two points that reach peak highest concentration, which is at 11:00 a.m. and at 2:00 p.m. and the value is 80.69 $\mu g/m^3$ and 86.69 $\mu g/m^3$ respectively. This value is influenced by visitors' vehicles that visit this shopping complex. Visitors taking this chance on weekend to bring their family or hang out with friends to this shopping complex and the value recorded is higher than on weekdays. There will be more visitors in this shopping complex on weekend compare to weekdays and at 11:00 a.m. and 2:00 p.m. are the peak hours for the vehicles movement in this car park. At 4:00 p.m. concentration of particulate matter 10 µm drop to 36.91 $\mu g/m^3$. After that, fluctuation of concentration occur until end of day at 12:00 a.m. However the fluctuation is in range 36.91 $\mu g/m^3$ to 43.88 $\mu g/m^3$, the difference drop and rise is not significant and lies below the limit. The fluctuation is mainly cause by the visitors entering and leaving the car park.

4.5 Overall Discussion for Particulate Matter 10 µm

From the result obtained, it can be conclude that, on weekdays (except Friday), Friday and Weekend, at certain hour concentration of Particulate Matter 10 µm exceed the allowable limit, which is 50 $\mu g/m^3$ from standard Guidelines by Malaysian Ambient Air Quality Guidelines.

For weekdays except Friday, the concentration exceed allowable limit at 11:00 a.m., 12:00 p.m., and 9:00 p.m. with concentration of 58.13 $\mu g/m^3$, 63.77 $\mu g/m^3$ and 75.57 $\mu g/m^3$ respectively.

For Friday, the concentration exceed allowable limit at 11:00 a.m., 12:00 p.m., 1:00 p.m., and 9:00 p.m. with concentration of 54.15 $\mu g/m^3$, 70.63 $\mu g/m^3$, 86.45 $\mu g/m^3$ and 54.95 $\mu g/m^3$ respectively.

For Weekend, the concentration exceed allowable limit at 10:00 a.m., 11:00 a.m., 12:00 p.m., 2:00 p.m., and 3:00 p.m. with concentration of 67.30 $\mu g/m^3$, 80.69 $\mu g/m^3$, 55.98 $\mu g/m^3$, 86.70 $\mu g/m^3$ and 75.41 $\mu g/m^3$ respectively.

Even though, the concentration of particulate matter 10 µm does not continuously exceed the permissible limit, but its concentration that exceed the allowable limit (cause poor air quality) for some points might lead to health implications especially to employees that their office is located at this car park level. They always exposed to this harmful concentration and repeatedly. The air quality at this car park is not promising to achieve a good quality due to the presence of concentration of particulate matter 10 µm above the permissible limit.

4.6 Concentration of carbon dioxide on weekdays (except Friday)

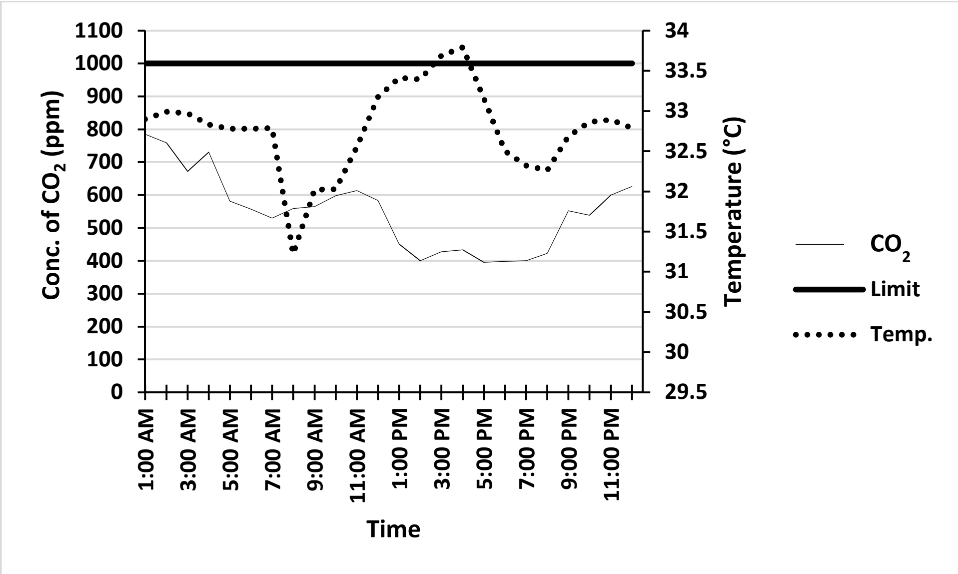

Figure 14: Concentration of Carbon Dioxide and Temperature VS Time on Weekdays (Except Friday)

Figure 14 shows the concentration of carbon dioxide and temperature VS time on weekdays except Friday. At 1:00 a.m., concentration of carbon dioxide recorded is 785.50 ppm. The concentration is decreased to 759.17 ppm at 2:00 a.m. At 3:00 a.m. the concentration decline to 672.33 ppm. After that, concentration of carbon dioxide rise to 730.60 ppm at 4:00 a.m. At 5:00 a.m., concentration of carbon dioxide is 581.13 ppm and continuously decrease until reach 529.57 ppm at 7:00 a.m. The concentration of carbon dioxide shows increment from 558.96 ppm at 8:00 a.m. until 613.77 ppm at 11:00 a.m. Then, the graph is drop to 583.76 ppm at 12:00 p.m. At 1:00 p.m., concentration of carbon dioxide reduce to 451.12 ppm and keep on decreasing until at 5:00 p.m. with concentration of 395.83 ppm. At 6:00 p.m. concentration of carbon dioxide is slightly increase to 398.53 ppm. After that, start from 7:00 p.m. with concentration of 400.00 ppm, the concentration of carbon dioxide is continually increase until 12:00 a.m. to 625.83 ppm.

4.7 Concentration of carbon dioxide on Friday

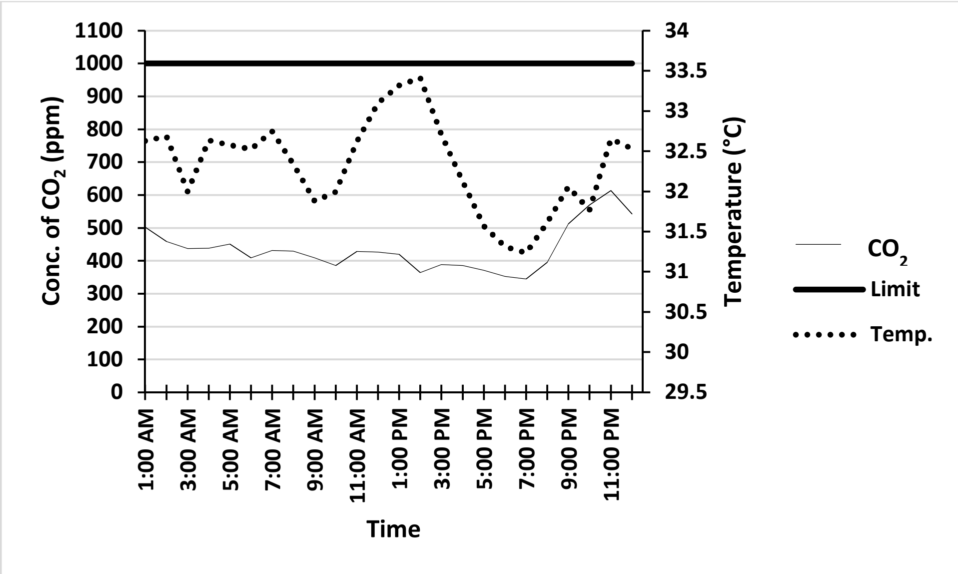

Figure 15: Concentration of Carbon Dioxide and Temperature VS Time on Friday

At 1:00 a.m., the concentration of carbon dioxide is 502.90 ppm. The concentration decrease to 458.57 ppm at 2:00 a.m. and keep on decreasing until reach concentration of 408.57 ppm at 6:00 a.am. It starts to increase again at 7:00 a.m. with concentration of 431.47 ppm. However, it drop again at 8:00 a.m. and 9:00 a.m. to 429.20 ppm and 408.80 ppm respectively. The concentration is still decreasing at 10:00 a.m. with concentration of 385.27 ppm. An increment carbon dioxide concentration can be observed at 11:00 a.m. with concentration of 428.47 ppm and has slightly decrease to 426.97 ppm at 12:00 p.m. The concentration of carbon dioxide start to decrease gradually at 1:00 p.m. from 419.33 ppm to 344.97 ppm at 7:00 p.m. After, the graph rise to 395.53 ppm at 8:00 p.m. At 9:00 p.m., the concentration increase tremendously until reach 512.36 ppm and growth to 613.30 ppm at 11:00 p.m. At 12:00 a.m., concentration reduce to 542.3 ppm.

4.8 Concentration of carbon dioxide for weekend

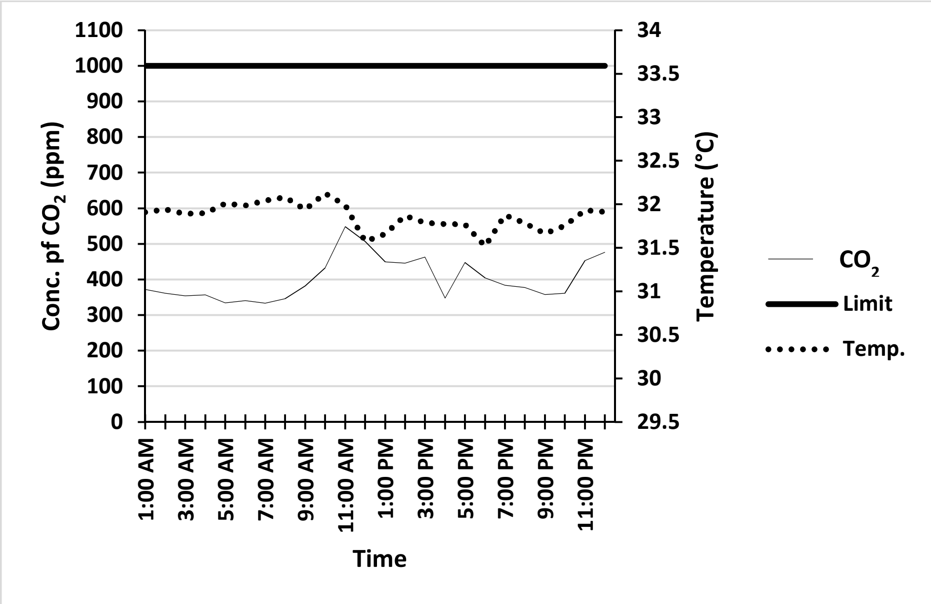

Figure 16: Concentration of Carbon Dioxide and Temperature VS Time on Weekend

At 1:00 a.m., concentration of carbon dioxide is 371.73 ppm. Then, it slightly decrease until 354.20 ppm at 2:00 a.m. At 4:00 a.m., the concentration increase to 357.17 ppm and drop to 334.00 ppm at 5:00 a.m. Concentration of carbon dioxide shows a little increment to 340.7 ppm at 6:00 a.m. Concentration of carbon dioxide decrease to 333.03 ppm at 7:00 a.m. However, from 8:00 a.m. to 11:00 a.m. the concentration of carbon dioxide is increased, from 345.93 ppm to 548.33 ppm. After that, at 12:00 p.m. the concentration is drop to 506.97 ppm and gradually decrease to 445.80 ppm at 2:00 p.m. The concentration increase to 463.23 ppm at 3:00 p.m. and then decrease to 348.00 ppm at 4:00 p.m. At 5:00 p.m., the concentration shows an increment to 447.7 ppm. From 6:00 p.m. to 9:00 p.m., concentration of carbon dioxide continually decrease which is from 404.83 ppm to 357.63 ppm. At 10:00 p.m. concentration of carbon dioxide increase which is the concentration is 360.90 ppm and keep on increasing until achieve 476.13 ppm at 12:00 a.m.

4.9 Analysis and Overall Discussion of Concentration of carbon dioxide

Carbon dioxide is produced by vehicle through complete combustion. The product of the complete combustion are carbon dioxide, water and heat. From previous study mentioned that when the concentration of carbon dioxide increase, the temperature at that area will increase as well. However, from the result that obtained Figure 14, Figure 15 and Figure 16, through this study, the correlation between carbon dioxide and temperature does not reflect to that statement.

Investigation has been conducted to find the reason behind this issue. It cause by the ventilation system inside this enclosed car park. The ventilation at this car park was design mainly to cater concentration of carbon dioxide. It will remove the carbon dioxide more effective. It has special sensor for carbon dioxide. Meanwhile, minimum air flow inside enclosed car park cause the temperature remains and take few hours to cool down.

From Figure 15 and Figure 16, it can be observed that the concentration of carbon dioxide is lower at noon and evening compare to midnight and early morning. Even though, towards midnight and early morning number of vehicles will be reduced. This is happen due to control system of ventilation at this car park. The ventilation has sensor to change the rate of removal of carbon dioxide. When the concentration is excessive or beyond a certain value, the ventilation will work more efficient and effective to reduce the concentration.

For overall, the most important, the concentration of carbon dioxide is below the allowable limit recommended by U.S. EPA for continuous exposure at all time. Visitors and employees for this car park are free from carbon dioxide effects. However, this concentration level must be maintained by conducting periodic monitoring for this car park with respect to concentration level of carbon dioxide and effectiveness of the ventilation.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The effects of air pollution inside enclosed car park cannot be taken by granted. It will give hazardous effects especially to human health. This study examined the concentrations of pollutants emphasis on particulate matter 10 µm and carbon dioxide in enclosed car park area and the data are analysed to find out whether the concentrations of the selected pollutants exceed the permissible limit or not. This study is significant and important because through the result obtained from this study, the concentrations pollutants inside that enclosed car park can be identified. If the concentrations exceed the limit, measures can be taken to enhance the air quality inside enclosed car park such as improving the ventilation system, study the contribution of fuels to the polluted air and find other possible causes leading to the air pollution inside enclosed car park. Only by knowing the concentrations of pollutants inside enclosed car park, further action can be conducted.

From observation, the fluctuation concentration of particulate matter 10 µm is mainly influenced by movement of vehicles in the car park instead of temperature. The more active movement of vehicles in the car park, the higher concentration of particulate matter 10 µm recorded. For particulate matter 10 µm, the allowable limit according to Malaysian Ambient Air Quality Guidelines is 50 $\mu g/m^3$. From the result obtained, concentration of particulate matter 10 µm is exceed the allowable limit at certain hour for each category (weekdays, Friday, weekend). Normally, the highest value recorded is at noon and night. Even though, the concentration is not continuously exceed the allowable limit, but it still can cause health implications especially to the employees at the car park because they stay at this car park area in a longer term. Due to the presence particulate matter 10 µm above the permissible limit, the air at this car park is not promising to accomplish good air quality. Action must be taken to reduce the concentration of particulate matter 10 µm, below the allowable limit to ensure health of employees and visitors in a safe condition.

From the result obtained for carbon dioxide profile, the correlation between carbon dioxide and temperature does not reflect to the literature review, which is, when the concentration of carbon dioxide increase the temperature will be increase. This due to the ventilation is this car park specially designed to cater carbon dioxide the most. So, it remove carbon dioxide effectively but due to minimum air flow inside the car park cause the temperature to remain and take few hours to cool down. The allowable limit for carbon dioxide is 1000 ppm according U.S. EPA for continuous exposure to. At this car park, the concentration of carbon dioxide is below the allowable limit at all time. Tendency to be affected by carbon dioxide at this area is very minimum. However, good maintenance is needed to maintain this concentration level. In conclusion, objectives of this study are achieved.

5.2 Recommendation

There are some recommendations that can be included for further study in the future. Firstly, widen the sampling area, which is the equipment should be placed at every level, since this study is only focusing at level 2 (P2) and increase duration of sampling. By doing this, more data and more accurate result can be obtained. The interpretations will be more detail. Secondly, measures all pollutants inside enclosed car park, since this study only carbon dioxide and particulate matter 10 µm. Thirdly, conduct a study to come out with a specific guideline for enclosed car park because enclosed car park do not have its own guideline. Enclosed car park environment is intermediate between outdoor and indoor environment. Lastly, conduct a further study to access the relationship between concentration of carbon dioxide and ventilation system inside this enclosed car park.

REFERENCES

Abdullah, A.M., Samah, M.A.B, & Tham, Y. J. (2012). An overview of the air pollution trend in Klang Valley, Malaysia. *Open Environmental Science* 6, 13-19.

Afroz, R., Hassan, M. N., & Ibrahim, N. A. (2003). Review of air pollution and health impacts in Malaysia. *Environmental Research 92*, 1-7.

Air Quality Expert Group. (2005). Particulate Matter in the UK: Summary. Defra, London.
Retrieved Jun 27, 2014 from http://archive.defra.gov.uk/environment/quality/air/airquality/publications/particulate-matter/documents/pm-summary.pdf

Augustine, C. (2012). Impact of air pollution on the environment in Port Harcourt, Nigeria. *Journal of Environmental Science and Water Resources*, 46-51.

Baldauf, R., McDonald, J., Heck, R., Cook, R., Rege, J., Bailey, C., Audette, L., & Armstrong, J.((2004). Management of motor vehicle emissions in the United States. In D. Elsom, & J. Longhurst, *Regional and local aspects of air quality management* . Southampton: WIT Press.

Bari, M. A., Macneill, M., Kindzierski, W. B., Wallace, L., Heroux, E. M., & Wheeler, A. J
(2014). Predictors of coarse particulate matter and associated endotoxin concentrations in residential environments. *Atmospheric Environment* 92, 221-230.

Bhatia, S. (2007). *Textbook of Air Pollution and Its Control.* New Delhi : Atlantic Publishers & Distributors (P) LTD.

Beauliue of America. (2009). Incomplete Combustion. Retrieved Jun 27, 2014 from http://www.blissflooring.com/bliss/about/warranties/information/~/media/Files/Technical%20Support%20Information/claims/Incomplete%20Combustion%20PDF.ashx

Celis, J. E., Morales, J. R., Zaror, C. A., & Inzunza, J. C. (2004). A study of the Particulate matter PM_{10} composition in the atmosphere of Chile. *Chemosphere* 54, 541-550

Centres for Disease Control and Prevention. (2012). Retrieved December 10, 2014, from CDC: http://www.cdc.gov/

Charron, A., & Harrison, R. M. (2005). Fine (PM2.5) and Coarse (PM2.5-10) Particulate
Matter on a Heavily Trafficked London Highway: Source and Processes. Retrieved Jun 26, 2014 from http://uk-air.defra.gov.uk/assets/documents/reports/cat05/0506061415_Fine_PM25_and_Coarse4.pdf

Chan, M., & Chow, W. (2003). Car park ventilation system: performance evaluation. *Building and Environment*.

Chow, W. K. (1995). On ventilation design for car parks. *Tunnelling and Underground Space Technology*, 1-21.

Chow, W. K., & Chan, M. Y. (2004). Car park ventilation system: performance evaluation.
Building and Environment 39, 635-643.

Colls, J. (2002). *Air Pollution.* London: Spon Press.

Conference Board of Canada. (2014). VOC Emission. Retrieved Jun 26, 2014 from http://www.conferenceboard.ca/hcp/details/environment/voc-emissions.aspx

Department of Environment, Malaysia. (2014). *Air Pollution*. Retrieved Jun 14, 2014, from http://apims.doe.gov.my/apims/General%20Info%20of%20Air%20Pollutant%20Index.pdf

Department of Environment, Australia. (2005). *Air Quality Fact Sheet*. Retrieved Jun 25, 2014, from http://www.environment.gov.au/resource/sulfur-dioxide-so2

Department of Health and Services Wisconsin. (2013). *Sulphur Dioxide*. Retrieved Jun 25, 2014, from http://www.dhs.wisconsin.gov/eh/chemfs/fs/SulfurDioxide.htm

Department of Road Transport. (2014). *Statistics for Motorcars Registration.* Retrieved Jun 14, 2014, from http://www.jpj.gov.my/en/statistik-pendaftaran-motokar

Department of Statistic. (2011). *Compendium of Environment Statistics 2011*. Retrieved Jun 14, 2014, from http://www.statistics.gov.my/portal/download_Environment/files/Compendium_2011/01-KANDUNGAN.pdf

Dominick, D., Juahir, H., Latif, M. T., Zain, S. M., & Aris, A. Z. (2012). Spatial assessment of air quality patterns in Malaysia using multivariate analysis. *Atmospheric Environment* 60, 5.

Elsom, D., & Longhurst, J. (2004). *Regional and local aspects of air quality management* . Southampton: WIT Press.

Feng, X., & Wang, S. (2011). Influence of different weather events on concentrations of particulate matter with different sizes in Lanzhou, China. *Environmental Sciences* 24, 665–674

Fenger, J. (2009). Air pollution in the last 50 years – From local to global. *Atmospheric Environment 43*, 1-10.

Foxall, K. (2010). Sulphur Dioxide : General Infromation. Retrieved Jun 25, 2014, from http://www.hpa.org.uk/webc/hpawebfile/hpaweb_c/1287148063808

Glossary of Volatile Organic Compounds (2014). Retrieved Jun 29, 2014, from http://www.cdc.gov/nceh/clusters/fallon/glossary-voc.pdf

Godish, T. (2004). *Air Quality*. United State of America: Lewis Publisher.

Halpern, P., Raskin, Y., Sorkine, P., & Oqanezov, A. (2004). Exposure to extremely high concentrations of carbon dioxide - a clinical description of a mass casualty incident. *Ann Emerg Med*. 43(2):196-9.

Hasenberg, L., Bender, R. (2014). Sulphur Dioxide. Retrieved Jun 29, 2014, from http://www.wiley-vch.de/books/sample/3527311262_c01.pdf

Ho, K .F., LeeL, S. C., Ho, W. K., Blake, D. R., Cheng, Y., Li, Y. S., Ho, S. S. H., Fung K., P. K. K. Louie, P. K. K. & Park, D. (2009). Vehicular emission of volatile organic compounds (VOCs) from a tunnel study in Hong Kong. *Atmospheric, Chemistry & Physics* 9, 7491–7504.

Ho, J., Xue, H., & Tay, K. (2004). A field study on determination of carbon monoxide level and thermal environment in an underground car park. *Building and Environment* 39, 67-75

Jacobson, M. Z. (2002). *Athmospheric Pollution: History, science, and Regulation*. Cambridge : Press Syndicate

Jeelani, H. A. (2013). The Impact of Traffic Emission on Air Quality in an Urban Environment. *Journal of Environmental Protection*, 205-217.

Jeremy, D. S., Peter, U.C., Feng H., Shaun, A. M., Alan, C. M., Zhengyu, L., Bette, O. B., Andreas, S. & Eddouard, B. (2012). Global Warming Preceded by Increasing Carbon Dioxide Concentrations during the Last Deglaciation. *Journal of Nature*, 49-54.

Jimoda, L. A. (2012). Effects of particulate matter on human health, the ecosystem, climate and materials: A review. *Working and Living Environmental Protection* 9, 27-44

Jonathan, W., & Ralf, K. (2007). *Volatile Organic Compounds in the Atmosphere*. Oxford: Blckwell Publishing Ltd.

Kakouei, A., Vatani, A., & Kamal, A. (2012). An estimation of traffic related CO2 emissions from motor vehicles in the capital city of, Iran. *Iranian Journal of Environment Health Science & Engineering*, 9-13.

Kampa, M., & Castanas, E. (2007). Human health effects of air pollution. *Environmental Pollution*, 1.

Karakatsani, A., Analitis, A., Perifanou, D., Ayres, J.G., Harrison, R.M., Kotronarou, A., Kavouras, I.G., Pekkanen, J., Hameri, K., Kos, G.P.A., de Hartog, J.J., Hoek, G., & Katsouyanni, K. (2012). Particulate matter air pollution and respiratory symptoms in individuals having either asthma or chronic obstructive pulmonary disease: a European multicentre panel study. *Environmental Health* 11, 75.

Klingenberg, H. (1996). *Automobile Exhaust Emission Testing*. Germany: Springer.

Krarti, M., & Ayari, A. (2001). Ventilation for enclosed parking garages**.** *ASHRAE* 43, 52-55

Li, Y., & Xiang, R. (2012). Particulate pollution in an underground car park in Wuhan, China. *Particuology* 11, 94-98.

Lopez, T. G., Sanchez, A. S., & Molina, C. G. (2013). Energy, environmental and economic analysis of the ventilation system of enclosed parking garages: Discrepancies with the current regulations. *Applied Energy,* 622-630.

Madhoun, W. A., Ramli, N. A., & Yahaya, A. S. (2012). Monitoring the total volatile organic compounds (TVOCs) and benzene emitted at different locations in Malaysia. *Engineering Science* 8, 61-69.

Middleton, N., Yiallouros, P., Nicolaou, N., Kleanthous, S., Pipis, S., Zeniou, M., Philip, D., & Koutrakis, P. (2010). Residential exposure to motor vehicle emissions and the risk of wheezing among 7-8 year-old schoolchildren: a city-wide cross-sectional study in Nicosia, Cyprus. *International Journal of Health Geographics,* 9-28.

Ndoke, P. N., Akpan, U. G., & Kato, M. E. (2006). Contributions of Vehicular Traffic to Carbon Dioxide Emissions in Kaduna and Abuja, Northern Nigeria. *Leonardo Electronic Journal of Practices and Technologies*, 81-90.

Nilrit, S., Sampanpanish, P., & Bualert, S. (2013). Emission of CH4 and CO2 emitted from vehicles. *American Journal of Environmental Science,* 38-44.

Othman, N. (2013). Profiling of indoor air pollutants and possibility of ozone formation. Final Year Dissertation, Civil Engineering Department, University Technology PETRONAS, Malaysia.

Ogilvie, K. (2005). Primer on Volatile Organic Compounds. Retrieved Jun 29, 2014, from http://www.pollutionprobe.org/report/vocprimer.pdf

Organization, W. H. (2005). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. 22.

Olumayede, E. G., & Okuo, J. M. (2011). Variation characteristics of volatile organic compounds in an urban atmosphere in Nigeria. *Environment Study* 21, 177-186.

Papakonstantinou, K., Chaloulakou, A., Duci, A., Vlachakis, N., & Markatos, N. (2003). Air quality in an underground garage: computational and experimental investigation of ventilation effectiveness. *Energy and Buildings* 35, 933-940.

Pascal, M., Falq, G., Wagner, V., Chatignoux, E., Corso, M., Blanchard, M., Host, S., Pascal, L., Larrieu, S. (2014). Short-term impacts of particulate matter (PM10, PM10e2.5, PM2.5) on mortality in nine French cities. *Atmospheric Environment* 95, 175-184

Petrovic, M., & Trajkovic, S. (2010). Air pollution as the cause of urban stress. A case study: Nemanjica Boulverad, Nis, Serbia. *Architecture and Civil Engineering*, 403-412.

Pritchard, J. D. (2007). Sulphuric Acid. Retrieved Jun 29, 2014, from http://www.hpa.org.uk/webc/hpawebfile/hpaweb_c/1202115622321

Pundir, B. (2007). *Engine Emissions: Pollutant Formation and Advance in Control Technology*. Oxford: Alpha Science.

Qiu, H., Yu, I.T., Tian, L., Wang, X., Tse, L.A., Tam, W., Wong, T.W. (2012). Effects of coarse particulate matter on emergency hospital admissions for respiratory diseases: a time series analysis in Hong Kong. *Environmental Health Perspectives*
120, 572-576.

Roger, A., & Janet, A. (2003). Atmospheric degradation of volatile organic compounds. *Chemical* 103, 4605-4638.

Salahudin, S. N., Abdullah, M. M., Newaz, N. A. (2013). Emissions: Sources, policies and development in Malaysia. *Education and Research* 1, 7.

Schwela, D., & Zali, O. (2002). *Urban Traffic Pollution*. New York: Spon Press.

Smith, S. J., Andres, R., & Wingley, T. M. L. (2001). Global and regional anthropogenic sulphur dioxide emission. *Global Planet Change* 29(1-2), 99-119.

Sulaiman, R., Din, N., Ishak, N. H. (2007). Indoor Air Quality in Selected Underground Car Park in Malaysia: Studies on Ventilation System and the Design Layout. Retrieved Jun 29, 2014, from http://www.inive.org/members_area/medias/pdf/inive/iaqvec2007/sulaiman.pdf

Takeshita, T. (2011). Global scenarios of air pollutant emissions from road transport through to 2050. *Canadian Center of Science and Education*, 112-123

The International Volcanic Health Hazard Network. (2014). Sulphur Dioxide. Retrieved Jun 29, 2014, from http://www.ivhhn.org/index.php?option=com_content&view=article&id=82

Tomasevic, M., Mijic. Z., Aninic, M., Stojic, A., Perisic, M., Kuzmanoski, M., Todorovic, M., & Rajsic, S. (2013). *Air Quality Study in Belgrade: Particulate Matter and Volatile Organic Compounds as Threats to Human Health*. Texas: Nova Science Publishers, Inc.

U.S. National Library of Medicine. (2014). Volatile Organic Compounds. Retrieved Jun 26, 2014, from http://toxtown.nlm.nih.gov/text_version/chemicals.php?id=31

Wallington, T. J., Kaiserb, E. W., &Farrell, J. T. (2006). Automotive fuels and internal combustion engines: a chemical perspective. *Chemical Society* 35, 335-347.

Warrington Borough Council Portal. (2012). *What is air quality and why does it matter?* Retrieved June 10, 2014, from Warrington Borough Council: http://www.warrington.gov.uk/info/200851/air_quality_and_pollution_control/730/what_is_air_quality_and_why_does_it_matter

Weuve, J., Puett, R.C., Schwartz, J., Yanosky, J.D., Laden, F., Grodstein, F. (2012). Exposure to particulate air pollution and cognitive decline in older women. *Archives of Internal Medicine* 172, 219-227.

World Health Organization. (2005). Health Effects of Particulate Matter. Retrieved Jun 26, 2014 http://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf

APPENDICES:

Processed Data for Carbon Dioxide on Weekdays except Friday.

Time	CO2 (ppm)	Temp	Limit (ppm)
1:00 AM	785.5	32.89967	1000
2:00 AM	759.16667	32.991	1000
3:00 AM	672.33333	32.96867	1000
4:00 AM	730.6	32.832	1000
5:00 AM	581.13333	32.78033	1000
6:00 AM	556.7	32.77933	1000
7:00 AM	529.56667	32.78567	1000
8:00 AM	558.96296	31.22111	1000
9:00 AM	564.83333	32.022	1000
10:00 AM	597.53333	32.027	1000
11:00 AM	613.76667	32.55267	1000
12:00 PM	583.75862	33.17552	1000
1:00 PM	451.12346	33.41444	1000
2:00 PM	400.26667	33.39133	1000
3:00 PM	427.8	33.688	1000
4:00 PM	433.35593	33.79237	1000
5:00 PM	395.83333	33.15433	1000
6:00 PM	398.53333	32.50067	1000
7:00 PM	400.46667	32.321	1000
8:00 PM	422.63333	32.26167	1000
9:00 PM	552.6	32.68433	1000
10:00 PM	538.46667	32.86133	1000
11:00 PM	599.66667	32.89233	1000
12:00 AM	625.82759	32.78862	1000

Processed Data for Carbon Dioxide on Friday.

TIME	CO2 (ppm)	Temp	Limit (ppm)
1:00 AM	502.9	32.62933	1000
2:00 AM	458.56667	32.685	1000
3:00 AM	437.73333	32.00	1000
4:00 AM	438.3	32.63533	1000
5:00 AM	451.26667	32.57433	1000
6:00 AM	408.56667	32.526	1000
7:00 AM	431.46667	32.74767	1000
8:00 AM	429.2	32.339	1000
9:00 AM	408.8	31.87667	1000
10:00 AM	385.26667	31.99367	1000
11:00 AM	428.46667	32.62033	1000
12:00 PM	426.96667	33.09933	1000
1:00 PM	419.33333	33.318	1000
2:00 PM	364.36667	33.412	1000
3:00 PM	388.96667	32.70633	1000
4:00 PM	385.9	32.11967	1000
5:00 PM	370.6	31.56733	1000
6:00 PM	352.1	31.31167	1000
7:00 PM	344.96667	31.23167	1000
8:00 PM	395.53333	31.613	1000
9:00 PM	512.36667	32.056	1000
10:00 PM	569.26667	31.76667	1000
11:00 PM	613.33333	32.65033	1000
12:00 AM	542.3	32.53103	1000

Processed Data for Carbon Dioxide on Weekend.

Time	CO2	Temp	Limit
1:00 AM	371.7333	31.91	1000
2:00 AM	361.2667	31.941	1000
3:00 AM	354.2	31.89167	1000
4:00 AM	357.1667	31.898	1000
5:00 AM	334	32.007	1000
6:00 AM	340.7	31.985	1000
7:00 AM	333.0333	32.042	1000
8:00 AM	345.9333	32.08167	1000
9:00 AM	382.1333	31.939	1000
10:00 AM	431.9667	32.125	1000
11:00 AM	548.3333	31.98833	1000
12:00 PM	506.9667	31.57433	1000
1:00 PM	449.7667	31.65933	1000
2:00 PM	445.8	31.86667	1000
3:00 PM	463.2333	31.78867	1000
4:00 PM	348	31.77233	1000
5:00 PM	447.7	31.77033	1000
6:00 PM	404.8333	31.51933	1000
7:00 PM	383.4667	31.87633	1000
8:00 PM	377.5	31.782	1000
9:00 PM	357.6333	31.66333	1000
10:00 PM	360.9	31.756	1000
11:00 PM	453.0333	31.93033	1000
12:00 AM	476.1333	31.91067	1000

Processed Data for Particulate Matter 10 µm on Weekdays except Friday.

Time	PM_{10} µg/m^3	Temp	Limit
1:00 AM	37.8	32.89967	50
2:00 AM	34.2	32.991	50
3:00 AM	28	32.96867	50
4:00 AM	26.7	32.832	50
5:00 AM	27.5	32.78033	50
6:00 AM	28.4	32.77933	50
7:00 AM	26.264	32.78567	50
8:00 AM	29.70444444	31.22111	50
9:00 AM	43.813	32.022	50
10:00 AM	43.68933333	32.027	50
11:00 AM	58.113	32.55267	50
12:00 PM	63.77111111	33.17552	50
1:00 PM	49.02518519	33.41444	50
2:00 PM	34.14266667	33.39133	50
3:00 PM	39.062	33.688	50
4:00 PM	37.32186441	33.79237	50
5:00 PM	40.05766667	33.15433	50
6:00 PM	33.301	32.50067	50
7:00 PM	34.14066667	32.321	50
8:00 PM	36.35666667	32.26167	50
9:00 PM	75.56833333	32.68433	50
10:00 PM	40.542	32.86133	50
11:00 PM	30.79566667	32.89233	50
12:00 AM	39.42111111	32.78862	50

Processed Data for Particulate Matter 10 µm on Weekdays except Friday.

TIME	PM10(ug/m3)	Temp	Limit
1:00 AM	32.26	32.62933	50
2:00 AM	30.42	32.685	50
3:00 AM	25.28866667	32.00	50
4:00 AM	23.70266667	32.63533	50
5:00 AM	24.17	32.57433	50
6:00 AM	24.42833333	32.526	50
7:00 AM	42.329	32.74767	50
8:00 AM	44.30633333	32.339	50
9:00 AM	28.79166667	31.87667	50
10:00 AM	41.66366667	31.99367	50
11:00 AM	54.15066667	32.62033	50
12:00 PM	70.62555556	33.09933	50
1:00 PM	86.456	33.318	50
2:00 PM	41.593	33.412	50
3:00 PM	39.04666667	32.70633	50
4:00 PM	40.52	32.11967	50
5:00 PM	30.14233333	31.56733	50
6:00 PM	24.72966667	31.31167	50
7:00 PM	23.29366667	31.23167	50
8:00 PM	33.402	31.613	50
9:00 PM	54.94966667	32.056	50
10:00 PM	42.13266667	31.76667	50
11:00 PM	43.40633333	32.65033	50
12:00 AM	36.95642857	32.53103	50

Processed Data for Particulate Matter 10 µm on Weekend

TIME	PM10(ug/m3)	Temp	Limit
1:00 AM	25.115	31.91	50
2:00 AM	28.863	31.941	50
3:00 AM	16.72366667	31.89167	50
4:00 AM	14.82833333	31.898	50
5:00 AM	13.82633333	32.007	50
6:00 AM	10.68033333	31.985	50
7:00 AM	15.337	32.042	50
8:00 AM	35.481	32.08167	50
9:00 AM	35.32333333	31.939	50
10:00 AM	67.3	32.125	50
11:00 AM	80.687	31.98833	50
12:00 PM	55.98827586	31.57433	50
1:00 PM	38.48551724	31.65933	50
2:00 PM	86.69866667	31.86667	50
3:00 PM	75.40833333	31.78867	50
4:00 PM	36.91333333	31.77233	50
5:00 PM	42.14128671	31.77033	50
6:00 PM	33.916	31.51933	50
7:00 PM	27.72633333	31.87633	50
8:00 PM	40.16066667	31.782	50
9:00 PM	31.737	31.66333	50
10:00 PM	24.37433333	31.756	50
11:00 PM	43.87933333	31.93033	50
12:00 AM	36.252	31.91067	50